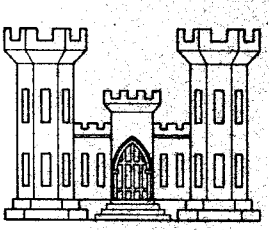

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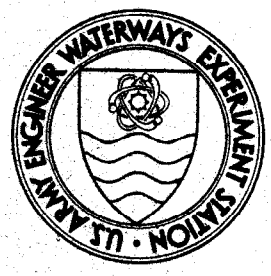

TECHNICAL REPORT D-78-51

INFLUENCE OF PREGERMINATION CONDITIONS ON THE VIABILITY OF SELECTED MARSH PLANTS

by

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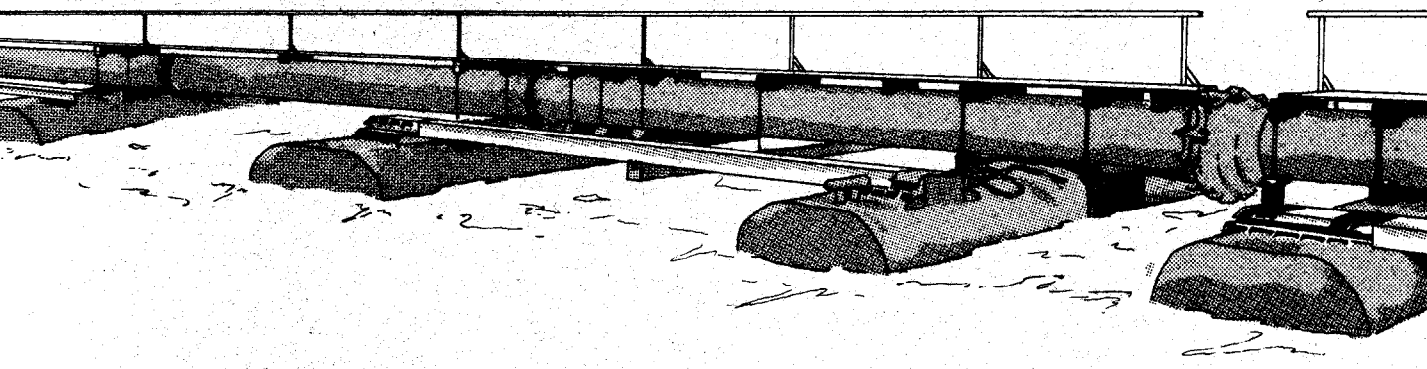
August 1978
Final Report



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SUBJECT: Transmittal of Technical Report D-78-51

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1. The technical report transmitted herewith represents the results of one of a series of research efforts (work units) undertaken as part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program. Task 4A was part of the Habitat Development Project (HDP) and had as its objective the development and testing of the environmental and economic feasibility of using dredged material as a substrate for marsh development.

2. Marsh development using dredged material was investigated by the HDP under both laboratory and field conditions. This report, "Influence of Pregermination Conditions on the Viability of Selected Marsh Plants," (4A21) evaluated seed storage and handling techniques for the purpose of maximizing viability. Thirteen common freshwater and salt marsh species were tested.

3. This study relates to the overall feasibility and applicability of marsh habitat development and represents one of many research items designed to evaluate the marsh development alternative. This and other relevant research has been synthesized in the Technical Report DS-78-16 entitled "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation" (4A24).

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

A brief state-of-the-art review and laboratory tests were conducted to determine the viability and germination requirements of seed from 13 marsh plant species and to determine proper methods of seed storage and handling techniques to maximize viability. Selected species which exhibited considerable dormancy were also subjected to various gas and hormone treatments in an effort to break seed dormancy. The 13 species examined included

(Continued)

20. ABSTRACT (Continued)

sea ox-eye (Borrichia frutescens), Lyngby's sedge (Carex lyngbyei), slough sedge (Carex obnupta), tufted hairgrass (Deschampsia caespitosa), marsh elder (Iva frutescens), soft rush (Juncus effusus), broadleaf arrowhead (Sagittaria latifolia), woody glasswort (Salicornia pacifica), tule (Scirpus validus), smooth cordgrass (Spartina alterniflora), big cordgrass (Spartina cynosuroides), Pacific cordgrass (Spartina foliosa), and salt-meadow cordgrass (Spartina patens).

After initial testing of seed viability using a tetrazolium solution, seeds were stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution for either 90 or 180 days. After storage, seeds were germinated at different day-night temperatures and the maximum percent seed germination was determined.

Maximum percent germination for all species tested was 94 percent for slough sedge after storage in distilled water for 90 days and 25°C day temperatures and 10°C night temperatures. Similar results were obtained for this species after storage in 10 ppt salt solution for 180 days and exposure to the same day-night temperatures. It took four weeks to obtain maximum germination after storage at these two conditions.

The species having the lowest maximum germination rate was saltmeadow cordgrass with only 15 percent. This low germination rate, however, may be a result of conditions particular to the seed lot tested as higher germination rates have been found for this species by other researchers.

The study results provide useful information about seed viability, dormancy, storage potential, and potential germination rates for the 13 marsh plant species tested. These parameters can be useful for indicating the feasibility of using certain species for future artificial marsh establishment programs when direct seeding is desired.

PREFACE

The work described in this report was performed under Amendment to Contract No. DACW57-76-C-0195 between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and the Seed Technology Laboratory, Washington State University, Pullman, Washington. The study was sponsored by the Office, Chief of Engineers, U. S. Army, under the Civil Works Dredged Material Research Program (DMRP) and was administered by the Environmental Laboratory (EL), WES.

The report was prepared for the Habitat Development Project (HDP) of the DMRP as part of Task 4A, "Marsh Development," Work Unit 4A21, "Influence of Seed Storage and Germination Conditions on the Viability and Germination of Selected Marsh Plant Species."

The research was conducted by Dr. G. A. Heuterman under the direction of Dr. J. D. Maguire, both of the Seed Technology Laboratory. Ms. Mary C. Landin, Biologist, and Dr. J. Scott Boyce, Research Soil Scientist, EL, developed the study outline. The study was conducted under the general supervision of Dr. Hanley K. Smith, Project Manager, HDP, and Dr. John Harrison, Chief, EL. Mr. Ellis J. Clairain, Jr., EL, was the contract manager. Ms. Landin made additions to the original text.

COL J. L. Cannon, CE, was Commander and Director of WES during the study. Mr. F. R. Brown was Technical Director, WES.

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INFLUENCE OF PREGERMINATION CONDITIONS ON THE VIABILITY OF SELECTED MARSH PLANTS

PART I: INTRODUCTION

Background

1. The Dredged Material Research Program (DMRP), of the U. S. Army Corps of Engineers, is seeking to provide definitive information on the environmental impacts of dredging and dredged material disposal operations. One aspect of the DMRP, the Habitat Development Project (HDP), has conducted marsh establishment studies throughout the United States, using dredged material as a substrate.

2. Attempts at marsh establishment on dredged material have been made at several (HDP) field sites using both direct seeding and sprigging methods. Direct seeding of marsh species appears to be the least expensive establishment procedure, particularly on large areas, provided that viable seed can be obtained and can be pretreated so that dormancy problems can be alleviated.

3. Past marsh establishment experiments at HDP field sites have been hampered by the fact that almost no information is available on many marsh species concerning seed dormancy factors, proper germination techniques, the relationship between seed viability and germination, or the effects of salinity on seed and seedlings. Additionally, development of practical seeding methods for marsh creation has been hampered by the lack of information on proper seed collecting and handling techniques and reliable seed quality indices. Basic understanding of the physiological factors associated with seed tolerance and response to salinity and immersion is also needed to enhance efforts to establish salt marsh species.

Objective

4. The objective of the study reported herein was to determine methods of seed storage and handling techniques for plant species used at HDP field sites. To address this objective, a state-of-the-art review and laboratory tests were conducted to determine the germination and viability requirements for eight Pacific coast species and five Atlantic and Gulf coast species. Species studied from the Pacific coast area were slough sedge* (Carex obnupta), Lyngby's sedge (C. lyngbyei), tufted hairgrass (Deschampsia caespitosa), soft rush (Juncus effusus), woody glasswort (Salicornia pacifica), broadleaf arrowhead (Sagittaria latifolia), Pacific cordgrass (Spartina foliosa), and tule (Scirpus validus). The five species from the Atlantic and Gulf coastal areas were sea ox-eye (Borrichia frutescens), marsh elder (Iva frutescens), smooth cordgrass (Spartina alterniflora), big cordgrass (Spartina cynosuroides), and saltmeadow cordgrass (Spartina patens).

5. Also examined in this study was the ability of certain hormones and gases to reduce seed dormancy of marsh species and to increase maximum germination. These techniques were required to elucidate the interactions between growth regulators and environmental conditions and to determine the metabolic processes involved in eliciting the observed responses. Reviews by Anderson (1968), and Berstein and Hayward (1958), and experiments by Ackerson and Youngner (1975), Hill (1908), Hyder and Yasmin (1971), Idris and Aslam (1975), Lazenby (1955b), Rubenstein (1974), Ryan et al. (1975), Shannon and Francois (1977), Sharma (1973), Wagner and Chapman (1970), and Weaver (1960) provided some insights and procedures for such investigations.

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* See Appendix A' for a complete list of common and scientific names used in this report.

PART II: STATE-OF-THE-ART REVIEW

Background

6. Numerous ecological studies have been conducted on the occurrence, abundance, and succession of plant species in areas subject to fluctuating environmental conditions. Establishment of techniques for marsh and aquatic plants on dredged material, however, has only recently received much attention (Broome et al. 1973; Garbisch et al. 1973). Redfield (1972) pointed out some of the problems of seed availability and salinity tolerance and indicated that direct seeding of adapted species was feasible in marsh areas. The use of seeding as a marsh establishment technique holds considerable promise in that it may be both inexpensive and easily applied to large areas (Broome et al. 1973; Garbisch et al. 1973). Seeding procedures, however, are complicated by the fact that relatively little is known about the maturation, dormancy, storage, or germination requirements for the seeds of most marsh plant species. Falco and Cali (1977) have reviewed the factors affecting germination and growth of various marsh grasses. Factors examined included thermoperiod, and salinity regimes during storage, germination, and seedling growth. It was determined that seeds of most salt marsh plants must be stored moist in order to remain viable and that increased saltwater concentration extended the viability period, apparently through increased osmotic pressure and inhibition of fungal growth. Seeds seemed to germinate primarily in response to photoperiods and fluctuating thermoperiods. An obligatory after-ripening period in seeds was observed and likely resulted from physiological processes involved in maturation of the seeds. Little systematic study of hormone treatment has been conducted on seeds of salt marsh plants.

7. Germination of seeds of salt marsh species tends to decrease with increased salinity in both water and soil. Salinity tolerances vary among both species and stages of plant development. Ecotypic variations in salinity tolerance occur among various species; therefore, transplanting of propagules from distant regions should be avoided and local seed

stock used whenever possible (Statler and Bateson 1969; McLaughlin 1974). Seeds of marsh plants constitute the major means of revegetating large intertidal areas (Kadlec and Wentz 1974). Much additional information, however, is needed on techniques for collecting, storing, pretreating, and sowing seeds in such areas. Seeds are also used for establishing nurseries for transplants which can provide an alternative means for vegetating marsh areas (Broome et al. 1973; Garbisch et al. 1973).

Seed Storage

8. Limited information is available regarding suitable storage conditions for seeds of marsh plants. Seneca's early research (Seneca 1969, 1972) with seeds of four dune-salt marsh grasses, beach grass (Ammophila breviligulata), beach panic (Panicum amarulum), saltmeadow cordgrass, and sea oats (Uniola paniculata) showed that seeds of some marsh plants must be stored moist if they are to remain viable; seeds stored in estuarine water remained viable for eight months. Mooring et al. (1971) found that seeds of smooth cordgrass must also be stored moist and that a low temperature ($6^{o}C$) will prevent desiccation for short periods. Seed-bearing spikes of smooth cordgrass and other salt marsh plants are shattered by the wind, and the seeds thus shed are subjected to prolonged exposure to water. Seeds harvested prior to shattering may exhibit varying degrees of dormancy due to physiological immaturity. Most marsh plant species have an obligatory after-ripening period.

9. Seneca (1969) further reported that storage viability could be extended up to twelve months in 40 parts per thousand (ppt) sodium chloride. Storage at higher concentrations may be feasible since 80 ppt sodium chloride did not kill the seed after storage for eight months. Apparently osmotic inhibition prevented germination of the seed under such conditions. Seeds may then germinate readily when placed in fresh water with suitable thermoperiods and suitable photoperiods.

Conditions Affecting Germination

Salinity

10. Salinity may affect the germination of seeds in several ways: (a) by decreasing the ease with which seed may take up water; (b) by facilitating entry of ions in sufficient amounts to be toxic; and (c) by altering dormancy-imposing conditions. Interactions among these stated factors contribute to the relative salt tolerance of many marsh species and govern the responses of their seeds. Various inherent features of seeds, such as physiological immaturity, impermeable seed coverings, and preconditioning, may alter seed responses. Salt tolerance of seeds and seedlings may vary greatly from that of respective mature plants. The basis for such physiological reactions to salinity are reviewed by Bernstein and Hayward (1958) who showed a decrease in germination percentages and rates in many cases, greater tolerance under cool conditions, a prolonging of viability in the imbibed state under saline conditions, and alleviation of osmotic inhibition by gibberellic acid.

11. Barton (1961) reported on seed preservation and longevity of seeds of aquatic plants which are dependent on storage conditions that prevent desiccation. Seeds of Scirpus spp. that were dormant when harvested required several months of after-ripening when stored in freshwater at $4^{\circ}C$. Some of these seeds even showed extended viability when properly stored. Sagittaria spp. showed similar requirements.

12. Anderson (1968) and Harris and Marshall (1960) indicated tule germinated differently depending on seed maturity at the time of collection and on water storage conditions. Storage in water for six months gave best germination results. Broadleaf arrowhead germinated best after seven months when stored in water. Scarifying the seed coat was also beneficial in obtaining prompt and maximum response.

13. Salinity encountered in marsh situations can have considerable effect on germination, but response varies with species and with salt concentrations. Allen (1956) indicated that smooth cordgrass could germinate at 60 to 80 ppt salt concentrations while saltmeadow cordgrass

only tolerated up to 40 ppt. European glasswort (Salicornia europaea) and Scirpus spp. tolerated 50 ppt. In all cases Allen found that increased salinity resulted in a 50 percent reduction in germination and slower seedling growth. Palimisano (1970) found similar osmotic inhibitions for seed of several salt marsh grasses. Adams (1963) illustrated an interaction between plant zonation and salinity.

14. Chapman (1960), Seneca (1969, 1972), and Ungar (1962) have shown that seeds of many species of halophytes, including European glasswort, germinated best under freshwater conditions, and that they did not require saline environments for germination or growth. Many researchers have found that halophytes grow faster at lower salinities than at higher salinities. Ungar and Hogan (1970) indicated that pelecote (Iva annua) seeds could tolerate salt solutions up to 23 ppt and recover later in distilled water with no apparent injury. This would seem plausible, as the salinity also varies considerably in marsh situations depending upon many different factors. Salt tolerance would allow seeds to survive during periods of high salinity and then recover during periods of lower salinity (Seneca 1972). Macke and Ungar (1971) stated that the ability to withstand high salinities and then recover is an important attribute of halophytes. In contrast, most agronomic plants that have been studied do not show this ability (Uhvits 1946).

15. Ayers (1951) reported that certain non-halophytic species showed an increase in seed germination time and a decrease in germination percentage with increased salt concentration. Mooring et al. (1971) indicated this was also the case with the halophyte, smooth cordgrass. Ungar and Hogan (1970) found that a decrease in seed germination at high salt concentrations was not due to the toxicity of the ion but rather due to inhibition of the uptake of water. Ayers (1951) felt that the inability of seeds of some agronomic plants to germinate under saline conditions was due to both the lowering of the rate of water entry and to the entry of toxic ions.

16. Falco and Cali (1977), in an extensive survey of seed pregermination requirements and establishment techniques for salt marsh grasses, reported on experimentation conducted in the Southeastern

coastal region. They found that, of salt marsh plants tested, viability was high when seeds were stored in water (fresh to brackish).

17. Lazenby (1955a) studied the effect of the water table on seed germination of soft rush and found that water near the soil surface was essential for seedling growth. Richards and Clapham (1941) reported that seeds of soft rush needed light before they germinated. Harris and Marshall (1960) found that seeds of tule germinated readily after storing in glass cloth bags under water during the winter season. Barbour and Davis (1970) found variations in salinity tolerance of several marsh plants but that seeds were most tolerant in the dormant state. Vogl (1966), in rating salt marsh plants in California, found pickleweed (Salicornia virginica) was highly salt tolerant.

Photoperiod and thermoperiod

18. In general, seeds of marshland species require light for germination and respond favorably to alternating thermoperiod regimes. Dormant seeds tend to be more sensitive and germinte under narrower regimes, than nondormant seeds which germinate over a much wider range of photoperiods and thermoperiods. Little reported literature is available for the species included in this study; however, Landin (Mary C. Landin, Biologist, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1977, personal communication) indicated that WES research showed 5-10 and 10-25°C as suitable night-day thermoperiods for the Pacific coast species and 10-25°C and 20-35°C as being suitable for the Atlantic and Gulf coast species.

Gases

19. Various gases have been shown to have promotive effects on dormant seeds and may have additive effects on seeds of some species when applied in combination. Effects are variable, however, and may even be inhibitory in some cases.

20. Ethylene stimulates the germination of certain seeds and is produced by germinating seeds of various species. It also seems to influence normal regulation of seed dormancy (Waring and Saunders 1971), usually in conjunction with other regulators. Ketring and Morgan (1969) observed that the embryonic axis of nondormant varieties of peanut

(Arachis hypogaea) actively produced ethylene during germination, whereas those of very dormant varieties produced only low levels of ethylene. However, it is also known that the growth of lettuce (Lactuca sativa) hypocotyls may be retarded by trapping either ethylene or carbon dioxide within the seed germination atmosphere (Negm et al. 1972; Esashi et al. 1975; Esashi et al. 1977a). Regulatory activities of ethylene are closely connected with those of carbon dioxide. The interrelationships are not uniform and may vary from competitive to mutually independent (Negm et al. 1972). Rijven (1974) found that ethylene and carbon dioxide are stimulatory in the absence of cytokinins and inhibitory in their presence with seed germination responses of fenugreek (Trigonella foenum-graecum). Spencer (1969) indicated that ethylene influence is inhibited by carbon dioxide when water uptake limits germination of small cranberry (Vaccinium oxycoccos) and other species.

21. Esashi et al. (1977b) indicated that high oxygen tensions, carbon dioxide, and ethylene were effective in breaking the dormancy of cocklebur (Xanthium sp.) seeds. They found that germination was reduced when endogenously evolved ethylene or carbon dioxide was removed, whereas the effect of high temperatures surprisingly stimulated ethylene production. Oxygen enrichment had no such effect. With witchweed (Striga lutea), ethylene stimulated germination of dormant seeds; carbon dioxide inhibited such action by ethylene (Egley and Dale 1970). Come and Tissaoui (1972) studied the interacting effects of imbibition, temperature, and oxygen on seed germination of nondormant apple (Malus spp.) seeds. After imbibition, oxygen supply to the seed embryo was restricted by the water layer in the seed coats and by phenolic constituents that fix part of the oxygen. When the temperature increased, the oxygen requirements of the embryo also increased, but the oxygen supply diminished due to dissolved oxygen in the water of the seed coat and to the effect of the phenolic compounds. Germination may thereby be inhibited.

22. Takayanagi and Harrington (1971) showed that lettuce seedlings seemed to develop faster with the ethylene treatment and responded with repressed elongation, thickened hypocotyl, crooked or helical hypocotyl

just below the cotyledon, and inhibited root growth. The malformed seedlings recovered when ethylene was removed. Katoh and Esashi (1975) and Esashi et al. (1997b), however, found that carbon dioxide promoted stem and coleoptile elongation, suggesting that stimulation of seed germination by endogenous carbon dioxide may have been associated with its accelerating effect on both the axis and cotyledon enlargement. Variation in results may have been due to the dormant or nondormant state of the seeds.

Hormones

23. Various growth-regulating compounds exist in seed and interactions exist among these compounds that inhibit or promote germination. Jacobsen (1973) studied gibberellic acid (GA), ethylene, and abscisic acid (ABA) control of barley (Hordeum sp.) seed germination, and found that GA was most effective in reducing ABA inhibition when ethylene was also present. Amen et al. (1970) studied saltgrass (Distichlis spicata) seeds where ABA effectively inhibited germination; however, GA and kinetin were ineffective in breaking seed dormancy in this species. Tao et al. (1976) showed a synergistic effect of kinetin and ethrel on the release of seed dormancy in lettuce seed.

24. Varied reactions occur under saline conditions. Kaufman and Ross (1970), in studies of water potential, temperature, and kinetin effects on seed germination in soil and solute systems, reported that treatment with kinetin caused germination enhancement over a range of salt solutions when heat sensitive lettuce seeds were tested.

25. Dunlap and Morgan (1977), while also working with lettuce seeds, indicated that the reversal of dormancy by kinetin was always enhanced by the addition of gibberellic acid (GA). Oegema and Fletcher (1971) found that the removal of the seed coat of veintinnilla (Asclepias curassavica) seeds led to rapid and complete germination, whereas cutting the seed coat in various ways resulted in partial germination.

PART III: METHODS AND MATERIALS

Seed Collection, Treatment, and Storage

26. Seeds were collected for each species in the localities of HDP field sites and delivered to the Seed Technology Laboratory, Pullman, Washington. Approximately 5,000 seeds per plant species were collected using techniques established at other HDP sites.

27. Wilbur E. Ternyik, Wave Beachgrass Nursery, Florence, Oregon, collected the following seeds from the locations indicated below:

a. Broadlead arrowhead seeds in a freshwater marsh at Albany, Oregon;

b. Tule and Lyngby's sedge seeds in a brackish area at the north fork of the Siuslaw River near Florence, Oregon;

c. Soft rush seeds at the Golf Course Swamp (freshwater) near the north fork of the Siuslaw River, Oregon;

d. Slough sedge seeds in the floodplain (fresh/brackish) on the south bank of the Siuslaw River at Florence, Oregon; and

e. Tufted hairgrass seeds at the Miller Sands HDP field site (fresh/brackish) in the Columbia River estuary near Astoria, Oregon.

28. The San Francisco Bay Marine Research Center, San Francisco, California, collected woody glasswort seeds in a salt marsh at Port Sonoma on the Napa River in Sonoma County, California, and Pacific cordgrass seeds at Muzzi Marsh (salt marsh) on the east side of Marin County, California.

29. Marsh elder, sea ox-eye, and big cordgrass seeds were obtained from a brackish marsh near Brunswick, Georgia, by Dr. Robert J. Reimold, Georgia Department of Natural Resources, Brunswick, Georgia. He also obtained saltmeadow cordgrass seeds from Jekyll Island, Georgia. Environmental Concern, St. Michaels, Maryland, collected smooth cordgrass seeds for the study at Portland, Maine.

30. Pacific cordgrass, smooth cordgrass, and big cordgrass seeds were shipped in freshwater. The smooth cordgrass seeds tended to sprout in shipment, an aspect that can be overcome by rapid shipping methods. The Pacific cordgrass seeds were shipped in a 40 ppt salt solution. They

were sealed in a plastic bag and arrived in a putrid condition; however, seeds were viable.

31. Upon delivery to the Seed Technology Laboratory, the seeds were immediately divided into equal portions and placed in 9-cm square covered petri dishes for storage. These petri dishes were used for all seeds except woody glasswort, for which round 5-cm petri dishes were used due to the small size of the seeds.

32. All seeds were stored in the dark at 5°C. Seeds were stored for periods of 90 or 180 days in the following treatments: dry, distilled water, 10 ppt salt solution, and 35 ppt salt solution. The salt solutions were made from Instant Ocean Synthetic Sea Salt.[a] Fifty millilitres of solution were added to each dish; for the 90- and 180- day-storage periods, it was found that no additional solution was required.

33. Special procedures were necessary to remove sterile florets, chaff, and other extraneous materials from the seed mass of several species studied. When tetrazolium tests were made to determine viability, they revealed very low percentages of stained seeds (indicating viability). The samples were blown in an Erickson[b] seed blower to remove light seeds and then retested. Seeds with impervious seed coats or adherent structures that interfered with the staining process were scarified so the solution could come in contact with the embryo. These methods were required for seeds of marsh elder, tufted hairgrass, broadleaf arrowhead, and soft rush. The small size of some seeds also necessitated construction of a special vacuum counter (Erickson Company) with minute holes to hold the seeds under suction. The small seed size of soft rush and broadleaf arrowhead required use of the General seed blower,[c] a more precise instrument for separating small seeds.

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[a] Aquarium Systems, Inc., Eastlake, Ohio.

[b] E. L. Erickson, Brookings, South Dakota.

[c] General seed blower, New Brunswick General Sheet Metal Works, New Brunswick, N. J.

Viability and Germination Experiments

34. The viability experiment was designed to ascertain the viability of seeds under storage regimes of differing temperatures and salt concentrations. Three germination environments were used as specified in the contract. Seeds of the Atlantic, Gulf, and Pacific coast species were germinated in alternating thermoperiods. The Atlantic and Gulf coast species were germinated in thermoperiods of 10-25 and 20-35°C, whereas the Pacific coast species were germinated at 5-10 and 10-25°C. Light was provided during the higher temperature and dark during the lower temperature for each germination test. Seeds were stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution at 5°C in the dark.

35. After the storage periods, the seeds were placed, unrinsed, on moistened sterile blotters in petri dishes. It was assumed that the seeds would have imbibed or had the same amount of sodium or chloride ions on the seed coats. Seeds were tested in the same sizes of petri dishes listed in paragraph 31. The larger dishes contained ten millilitres of solution and the smaller dishes contained two millilitres.

36. Four replications of 100 seeds each were used for each storage treatment except where the available seed sources were limited, in which case two replications were used. Shoot growth was measured by randomly sampling 10 shoots from each treatment and measuring the shoots to the nearest millimetre.

37. Distilled water was added during the course of the germination period as a means of controlling the amount of salts in each dish. This was necessary because of the variability in the amount of moisture required for seed germination and because seed is usually germinated in such media after storage in salt solutions.

38. Procedures for the germination tests were adapted from similar species as outlined in the Rules for Testing Seeds, Association of Official Seed Analysts (1970a). Tetrazolium testing procedures were adapted from the Tetrazolium Testing Handbook (1970b) using solution concentrations and preparation methods for similar species. Tetrazo-

lium chloride, a colorless solution, produces color reactions with viable seed embryo tissues, indicating initial viability of non-dormant and dormant seed. The position and distribution of color in the seed embryo are the primary indicators of viability as the intensity of staining will vary between species. Impermeable seeds require treatment to allow penetration of the tetrazolium solution to the embryo. Results from this study were determined from several replications.

Gas Experiments

39. Fifty-millilitre Erlenmeyer flasks were used for gas experiments in which varying concentrations of ethylene, carbon dioxide, and nitrogen were used on broadleaf arrowhead and tule seeds. Rubber septums were used to seal the flasks for the initial gas treatment. Aluminum foil covers were then used for the remainder of the germination period. Carbon dioxide traps were constructed of shell vials with stirring rods, with fluted paper being used as wicks for 0.2 ml of 1 M potasium hydroxide (Figure 1).

Rationale for Experiments

Viability studies

40. Procedures such as acid and alkaline treatment, plant hormone treatments, scarification, and heat application were methods considered of acceptable value in breaking dormancy when necessary. Viability of dormant seed can also be tested by staining with a tetrazolium solution.

41. The influences of seed storage conditions, length of storage, thermoperiods and photoperiods, on seed viability and germination were determined. Significant discrepancy between seed viability and germination required additional work to determine the cause of the discrepancy and to determine methods of breaking dormancy if dormancy was the cause. Seeds of the eight Pacific coast species were treated only under the two lower thermoperiods to simulate their natural growing conditions. While it was recognized that several species are fresh

to slightly brackish water plants, testing of salinity concentrations and durations was necessary to determine salt tolerance of the seeds and other responses such as dormancy and control of fungal contamination.

Gas studies

42. Literature indicated varying promotive effects from oxygen, carbon dioxide, and other gases depending on species involved and the state of dormancy of the seeds. Interactions with growth substances were also indicated. Limitations of time, labor, and facilities precluded extensive investigations in these matters, but several of the species found to be dormant in the initial tests were subjected to combinations of gases and growth regulators to ascertain benefits from such treatments in overcoming dormancy.

PART IV: RESULTS

Viability and Initial Germination

43. The comparative germination and viability results are presented in Table 1, indicating the germination potential and dormancy, if any, for the seeds when first received. Dormancy was assumed when a difference of 15 percent or more was observed between the germination and tetrazolium results. A variation of 10 percent was acceptable with two 100 seed replications.

44. Sea ox-eye seeds initially germinated 71 percent at 10-25°C, and tetrazolium staining showed positive deep red staining for 67 percent of the seed embryos tested after 24 hours. The seeds readily adsorbed the solution so no special pretreatment was required.

45. Lyngby's sedge seeds germinated 50 percent at 10-25°C, and tetrazolium staining after 48 hours in solution was 68 percent. Seeds were first soaked 24 hours in water, then bisected longitudinally to allow tetrazolium solution to penetrate. Seed staining color was a medium carmine shade, and embryos were readily distinguishable as viable or nonviable. Dormancy, apparently due to impermeable seed coats, was indicated by a wide difference (greater than 15 percent) between tetrazolium staining and the germination results obtained.

46. Slough sedge seeds received similar pretreatment for the tetrazolium test. Tetrazolium results showed 61 percent viable embryos compared to 63 percent germination obtained at 10-25°C.

47. Tufted hairgrass seeds germinated 83 percent at 10-25°C, and tetrazolium staining results indicated 83 percent viability after 24 hours in solution. Embryos were stained a deep carmine color. Seeds were pierced through the pericarp with a needle to facilitate staining.

48. Marsh elder seeds required blowing pretreatment to remove light seed structures. Resultant germination tests were 49 percent at 10-25°C whereas tetrazolium staining showed 66 percent viable embryos, with a deep carmine color after 24 hours. Marginal slicing of the seed coat was necessary to facilitate staining and visual evaluation.

Like the seeds from Lyngby's sedge, marsh elder seeds appear to have impermeable seed coats. Dormancy was indicated by the large difference between the results from the tetrazolium tests and the germination studies.

49. Soft rush presented some problems in evaluation of the seed quality due to the small seed size and presence of nonfilled seed units. Construction and delivery of a special vacuum counting head delayed conducting these experiments. Germination of seeds at 10-25°C was 62 percent, and tetrazolium results indicated 64 percent strong staining of the embryos after 24 hours in solution. Seeds were bisected longitudinally after soaking in water to allow penetration of the tetrazolium solution and evaluation of the staining pattern. Soaked seeds tended to form a gelatinous mass that made handling difficult. A sharp cutting blade was necessary to avoid crushing the embryos. Piercing seeds with a needle was not recommended due to inaccessibility of embryo for viewing the staining pattern. Embryo stain was only visible in such seeds when a clearing solution of lactophenol was applied to the seed coat. A stronger tetrazolium solution of one percent was also necessary to stain pierced seeds.

50. Woody glasswort seeds germinated readily at 92 percent in two weeks. Tetrazolium results indicated only 79 percent viability. This was likely due to difficulty in separating seeds from nonviable material and the necessary cutting of the seed coat to allow solution to penetrate. Embryos may be removed from the seed coat after staining for more extensive evaluation. Also, extending the staining period beyond 24 hours may increase detectability of a color change.

51. Broadleaf arrowhead seeds presented problems in evaluation of viability and germination. Much light, nonviable material was present in the sample as received, and blowing was required to remove this material from the seed units tested. This species also has an impermeable seed coat, although the seed coat is thin and papery. Longitudinal slitting of the seed coat was required to facilitate staining. It was then necessary to remove the embryos from the seed coats after staining in order to evaluate the viability. Staining progressed slowly, and 98

hours soaking in tetrazolium solution was required. A one percent solution was used to intensify the staining. Results of the tetrazolium test were 52 percent although the seeds only germinated one percent at 10-25°C, indicating a high degree of dormancy. Therefore, broadleaf arrowhead seeds were subjected to gases and growth regulator tests to determine optimum conditions for germination and means of overcoming dormancy.

52. Only one percent of the tule seeds germinated at 10-25°C. Tetrazolium results indicated 80 percent viability when tested in 0.1 percent tetrazolium solution for 24 hours. Seeds were soaked in water for 24 hours and then sliced longitudinally to allow penetration of solution and to facilitate evaluation of the staining pattern. Tule seeds were also tested with gases and growth regulators to promote germination.

53. Smooth cordgrass seeds germinated 45 percent at 20-35°C, and tetrazolium staining results indicated 94 percent viable seed after 24 hours. Evidently, some dormancy was present. The seeds were soaked for 24 hours in water in preparation for the tetrazolium test. Seeds were then bisected longitudinally at an oblique angle to avoid damage to the embryo. Viable tissue stained a deep red color after 24 hours in solution.

54. Big cordgrass did not indicate any appreciable dormancy. Seed germination at 10-25°C was 65 percent compared to 79 percent viable staining in tetrazolium. Seeds were pretreated by blowing to remove nonfilled seed units. In preparation for tetrazolium staining, seeds were soaked 24 hours in water, then bisected diagonally to expose the embryo to the staining solution and allow visual observation of the embryos.

55. The Pacific cordgrass seeds arrived in putrid condition, but viability was apparently not impaired. Initial germination of seeds was 44 percent at both 20-25°C and 20-35°C. Some dormancy was present as tetrazolium results indicated 81 percent viable seeds. Only two replications of 100 seeds each were used due to small size of the sample.

56. The saltmeadow cordgrass seeds required initial blowing to

remove unfertile florets. Subsequent germination was only seven percent at 10-25°C. Tetrazolium results showed 47 percent positive stain, indicating considerable dormancy for these seeds. Color development in 0.1 percent tetrazolium solution took 48 hours, indicating immaturity as a possible cause for low germination.

57. These results provided basic indications of possible dormancy in various species, and pretreatments and conditions for viability determinations.

Thermoperiods, Storage Duration, and Treatments

Sea ox-eye

58. Germination results of sea ox-eye seeds are indicated in Table 2. Seeds first germinated in water, then 10 ppt salt solution at 10-25 and 20-35°C. The 10-25°C thermoperiod regime was significantly better than 20-35°C (Table 3 gives Duncan's New Multiple Range Analysis) when seeds were germinated in distilled water and 10 ppt salt solution compared to 35 ppt salt solution. Germination was also several weeks faster under the 10-25°C thermoperiod. This effect carried through the 90 and 180 day soaking periods as shown in Figures 2 and 3. When seeds were germinated at the optimum thermoperiod (10-25°C), storage conditions had little effect on germination rate; dry and soaked seeds gave comparable results. Ten ppt salt solution gave the best results over dry storage, distilled water, and 35 ppt salt solution. With a 20-35°C thermoperiod, germination was better in distilled water.

Lyngby's sedge

59. Seed germination results for Lyngby's sedge are presented in Tables 4 and 5. A thermoperiod of 10-25°C produced better and more rapid germination than 5-10°C following 0, 90, and 180 days storage when seeds were stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution. Storage for 90 and 180 days produced significantly better germination. Figures 4 and 5 show that these seeds germinated well after dry storage, in distilled water, and in 10 ppt salt solution, but not in 35 ppt salt solution where very poor germination ranging from 0 to 12 percent was obtained. Some

dormancy may have been involved, as seed germinated better after storage treatments.

Slough sedge

60. Germination of slough sedge seeds is indicated in Tables 6 and 7, where poor germination results were obtained with 5-10°C. At 10-25°C, greater germination was obtained and more rapid germination occurred, particularly after soaking seeds for 90 and 180 days. Figures 6 and 7 show that soaking seeds in distilled water produced better germination than dry storage in salt solutions, regardless of storage duration.

Tufted hairgrass

61. With this species a thermoperiod of 10-25°C produced better seed germination than 5-10°C for unsoaked seeds and for 90- and 180-day storage periods regardless of storage treatment (Tables 8 and 9). Germination of dry stored seeds and those stored in distilled water were generally better than those stored in salt solutions, particularly in the 35 ppt solution which had adverse effects on the rate of germination (Figures 8 and 9).

Marsh elder

62. Germination of marsh elder seeds was higher with the thermoperiod of 10-25°C compared to 20-35°C, although storage in distilled water and 10 ppt salt solution subsequently gave better results with 20-35°C as dormancy dissipated (Tables 10 and 11). Figures 10 and 11 show dry storage to be effective as well as storage in distilled water. Storage in salt solutions generally had adverse effects on germination. None of the germination regimes or treatments overcame the dormancy enough to produce the viability potential indicated by the initial tetrazolium staining.

Soft rush

63. The thermoperiod of 5-10°C was very adverse for germination of soft rush compared to 10-25°C. Significant germination was obtained at this regime only after soaking seeds in distilled water for 90 and 180 days (Tables 12 and 13). Soaking in distilled water was most effective for germination whether seeds were stored dry or soaked for 90

and 180 days. Figures 12 and 13 show higher germination was obtained for dry-stored seeds compared to those soaked in solutions. Ten ppt salt solution produced satisfactory results initially but lower germination was obtained after storage for 90 and 180 days.

Broadleaf arrowhead

64. Broadleaf arrowhead seeds were extremely dormant, germinating very slowly and never reaching viability potential indicated by initial tetrazolium staining. No germination was obtained for unstored seeds as shown in Tables 14 and 15. A thermoperiod of 10-25°C was more effective in promoting germination compared to a constant 30°C. Figures 14 and 15 show very slow initial seed germination after storage for 90 days. Best results were produced when seeds were stored in distilled water versus dry or salt solution.

Dormancy Breaking Treatments

Broadleaf arrowhead

65. Various gases known to influence germination were applied to broadleaf arrowhead seeds to overcome dormancy and promote prompt maximum germination. Results are illustrated in Figures 16 and 17. Increased carbon dioxide in a closed system increased germination significantly more than conditions in both open and closed controls having normal atmospheric conditions. Increased germination was also obtained with carbon dioxide plus ethylene, ethylene alone, and nitrogen. Oxygen alone and ethylene plus oxygen had negative effects on germination.

66. Based on positive results with some of these various gases, the treatments were combined with growth promoters. Gibberellin and kinetin alone and in combination were applied with carbon dioxide, oxygen, ethylene, and nitrogen individually (Table 16). Results of the interaction effects of gases with hormones on broadleaf arrowhead seed germination are presented in Figure 16.

67. In the carbon dioxide treatment the growth regulators had little promotive effects, and best germination was obtained with the water control. With the ethylene-kinetin treatment, somewhat better

germination was produced compared to gibberellin or gibberellin-kinetin. Results with nitrogen and growth regulators were ineffective, as were the growth regulators in a combined carbon dioxide-ethylene atmosphere.

Woody glasswort

68. Woody glasswort seeds germinated readily under most conditions with significantly higher germination initially at 10-25°C compared to 5-10°C, and rapid germination occurring in 2-3 weeks. Tables 17 and 18 show good germination of dry seeds when initially tested. Distilled water and 10 ppt salt solution produced better results than when seeds were imbibed in 35 ppt salt solution. After storage for 90 and 180 days the seeds stored in distilled water germinated better than those in salt solutions. Storage in 35 ppt salt solution gave rather high results when seeds were placed in distilled water. Dry stored seeds were slow to germinate initially but did produce high results comparable to wet stored seeds after several weeks in the germinator. Figures 18 and 19 indicate that viability was generally maintained over storage time and dissipated somewhat when seeds were stored in salt solutions.

Tule

69. Germination of tule seeds was only obtained at 10-25°C, with no results obtained at the 5-10°C thermoperiod (Tables 19 and 20). Low initial germination confirmed the high dormancy level indicated in initial germination and viability determinations. Unsoaked seeds did not germinate at all. Storage for 90 and 180 days improved germination somewhat although dormancy was still present and complete germination potential was not reached. Dry storage was ineffective and very little germination was produced after 90 and 180 days. Soaking seeds in water for 90 days produced good germination. After 180 days, favorable germination results were obtained with seeds that had been stored in water in 10 ppt and 35 ppt salt solutions (Figure 20). Experiments with gases and growth promoters were conducted with inclusive results. Dormancy was not overcome by any of these treatments in tule seeds.

Smooth cordgrass

70. The germination results of smooth cordgrass seeds are given

in Tables 21 and 22 where it is indicated that the 20-35°C thermoperiod initially produced higher germination than 10-25°C. This trend continued throughout the storage periods under different imbibition conditions. Considerable dormancy was present in the smooth cordgrass seeds, and complete viability potential was not realized in the course of the experiments. Dry storage was very ineffective; virtually no germination was obtained from seed stored in such manner. Storage in water, and in 10 ppt and 35 ppt salt solutions, produced acceptable germination after 90- and 180-day storage periods, with the salt solution storage treatments resulting in slightly better germination results as indicated in Figures 21 and 22. The fact that sprouting of smooth cordgrass seeds occurred in shipment reduced the potential for readily germinable seed for these experiments.

Big cordgrass

71. Seeds from big cordgrass germinated better at the 10-25°C thermoperiod compared to 20-35°C (Tables 23 and 24). Initial germination was slow, taking several weeks in all imbibition conditions before germination began. Dry storage for 90 days gave acceptable results, but after 180 days of dry storage, seed germination was much reduced (Figures 23 and 24). Soaking seeds for 90 and 180 days in distilled water or 10 ppt salt solution produced good germination; 35 ppt salt solution reduced germination. Slight dormancy of these seeds may have occurred, affecting actual germination obtained in the experiments.

Pacific cordgrass

72. Dormancy was evident in the initial germination and tetrazolium evaluations of Pacific cordgrass, and viability potential was not attained in these experiments. Tables 25 and 26 show germination at 10-25°C and 20-35°C following storage both dry and under varying solutions. Dry storage of the seeds was unsatisfactory as no germination was obtained at 90 or 180 days. Storage in distilled water was most satisfactory, although acceptable germination was obtained with storage in 10 ppt and 35 ppt salt solutions. Figures 25 and 26 show seed germination after storage 90 and 180 days in solutions was more rapid compared to initial germination in salt solutions. Limited

amounts of seeds were available, necessitating reduction of replications for each experimental treatment. Seeds were not available for further studies of the dormancy mechanism or tests to assess means of overcoming such dormancy. Condition of these seeds upon receipt indicated possible adverse effects from phenolic and other inhibitory compounds that would reduce germination obtained in these experiments.

Saltmeadow cordgrass

73. Tables 27 and 28 give the germination results for saltmeadow cordgrass seeds, which were generally low in all treatments. Low potential viability and initial germination obtained in the tetrazolium evaluation and first germination tests indicated poor seed quality and extreme dormancy. Figures 27 and 28 show that dry storage was less satisfactory than storage in water or salt solutions. Germination increased after storage for 90 days in the solutions. Little difference was obtained between the 10-25°C and 20-35°C thermoperiods. Since the potential germination of these seeds was assumed to be rather low, further pretreatment and dormancy breaking treatments were not conducted.

PART V: DISCUSSION

Broadleaf Arrowhead

74. Broadleaf arrowhead, characterized by variable leaves, is a marsh plant that grows in clumps from corms. These corms occur along a dense mat of rootstock and are edible by humans and wildlife. Broadleaf arrowhead spreads by both rootstock and seed. It occurs in inland and coastal freshwater marshes throughout most of the United States. The plants reach from knee to head height with leaves sometimes 30 cm or more long. Seed heads are on long stalks that protrude above the foliage. They are gathered by cutting seed stalks in season (July to September) and shattering. Broadleaf arrowhead is usually propagated by rootstock. Propagation from seed is also an acceptable method of propagation; however, germination is difficult. Initial seed viability studies indicated a high degree of seed dormancy which was not overcome by storage conditions or thermoperiods. Viability greatly deteriorated after 90 days dry storage. Special treatments, including increased carbon dioxide and ethylene gas exposure, were required to promote germination. Further study is required to perfect ways to promote germination if broadleaf arrowhead seeds are to be used in marsh establishment programs. Propagation by rootstock appears to be a more feasible method for marsh propagation than by seeding.

Lyngby's Sedge

75. Lyngby's sedge is a perennial grass-like sedge that spreads by both rootstock and seeds. It is fairly common in coastal brackish and salt marshes in northern North America and occurs from Alaska to California and Greenland to Quebec. Mature plants are usually about 20 to 40 cm high. Seeds are collected by hand gathering seed heads in season (July to September) and shattering the heads. This species is noted for poor seed production on alternate years by mature plants and also during its seedling year. Tests indicate that seeds may be stored dry,

but storage wet in fresh or brackish water is preferable. Salt solutions did not reduce viability but resulted in slower growing seedlings. The 10-25°C thermoperiod produced best germination indicating that some possible dormancy dissipated after 180 days of storage. Seeds soaked in water for 90 days germinated well but more slowly than at 10-25°C. Lyngby's sedge can present some problems with seed availability and possible dormancy, which should be considered in planting plans. Seeds can be stored wet for at least 180 days with little effect on viability.

Pacific Cordgrass

76. Pacific cordgrass is a slow-growing cordgrass that occurs along the Pacific coast, primarily in California and Oregon. It can withstand inundation and high salinities and occurs in association with woody glasswort. Stems are stout and 30 to 120 cm high. Seed heads are short, upright, and unbranched. This species is often called the west coast equivalent of smooth cordgrass, but the growth rates are decidedly slower in Pacific cordgrass. Seeds are gathered by collecting seed heads in August to September and shattering them by hand. Results indicated reasonable salinity tolerance and a high degree of dormancy. Dry storage was not suitable; seeds germinated well in distilled, in brackish, and in salt water, but dormancy persisted after soaking 180 days. Seeds germinated similarly at either 10-25°C or 20-35°C. Limited amounts of seeds precluded further testing and special treatments. Pacific cordgrass is a useful species for establishment in salt marshes. Direct seeding appears to be a feasible method of propagation in certain substrates. Seeds can be seasonally obtained and viability retained in excess of 180 days.

Woody Glasswort

77. Woody glasswort occurs in coastal and inland salt marshes, mainly along the coast from California to Alaska. It has a high

tolerance of salinity and inundation and, along with Pacific cordgrass, is likely to be the low marsh species occurring in a coastal marsh. This plant has fleshy stems, and spreads by rootstock, cuttings, and seeds. It grows from 25 to 30 cm high. Seeds may be obtained by gathering seed heads in season (July to September); however, seeds are difficult to obtain. This plant is most commonly propagated naturally with vegetative parts rather than seed. Seeds stored dry or in water maintained viability up to 180 days. Seeds germinated promptly at 10-25°C compared to much slower germination at 5-10°C. Dormancy was not a problem. Woody glasswort is very tolerant to high salinity up to 90 days. Best storage for seed was in distilled water with good germination still taking place after 180 days. With its high salinity tolerance and readily germinable seeds, Pacific glasswort represents a most useful species for marsh establishment. Seed collection, however, could be a problem because of limited availability.

Slough Sedge

78. Slough sedge is a rhizomatous plant that grows in dense clumps with stiff upright stems. It occurs primarily in fresh water/brackish water marshes. Its range is from British Columbia to California, and it occurs only in the Pacific Northwest. Plants may vary greatly in height, and have been found over 150 cm high; most commonly it is 30 to 100 cm high. Seed heads in this species do not droop as do many Carex species but are upright. The seed heads form in late June-July. They are collected by gathering in season (July to September) and threshing seeds manually. Results indicate seeds germinated best at 10-25°C compared to 5-10°C. No apparent dormancy occurred. Dry storage was satisfactory for 90 and 180 days, as was storage in distilled water. Brackish water storage reduced germination and slowed seedling growth. Reduced germination and slow growth in salt solutions indicates osmotic inhibition. Seed can be effectively used in marsh establishment. This species is adapted to low areas with frequent flooding. Storage in water is recommended to prolong viability.

Tule

79. Tule occurs in freshwater to slightly brackish coastal and inland marshes throughout the United States and eastern Canada. Stems are soft, flexible, and dark green in color. They are most often 1.5 to 2.5 m in height. Dense stands occur in regularly inundated areas. Seed heads are large, droopy clusters, with dark brown seeds. The seed heads are gathered in season (June to September) and shattered to collect seeds. These seeds are extremely difficult to germinate because they have tough, impermeable seed coats. Various researchers have worked with this wildlife food plant to induce artifical seed germination with poor results; however, it can be easily propagated by rootstock. Results indicated a high degree of dormancy with no initial seed germination. Dry storage was ineffective in overcoming dormancy. Soaking seeds in water was effective for obtaining reasonable germination. Only after 180 days was significant seed germination obtained with brackish and salt water storage. The thermoperiod of 10-25°C produced good germination results, but none occurred at 5-10°C. This species is useful in low fresh marsh establishment. Dormancy and specific temperature requirements could present problems in establishment by seed unless sufficient storage time occurs to dissipate the problems. Propagation by rootstocks is easier than seeding and offers greater potential for success.

Soft Rush

80. Soft rush occurs primarily in inland freshwater swamps and marshes over the entire United States but is most common in the southeast. This plant grows in dense clumps 40 to 80 cm in height. Its common name is a misnomer, as the stems are relatively stiff and hard to cut. It occurs at the edges of the marsh and cannot tolerate prolonged inundation. The many-clustered seed head produces many tiny dark seeds. These seeds are small and mucilagenous, tending to stick together (Lazenby 1955b). Seeds are gathered by removing the seed heads

in season (June to September) and shattering the heads by hand. Test results indicated dry storage or storage in water was best for maintaining seed viability of this species. Brackish water (10 ppt) reduced seed germination percentages and rates while salt water (35 ppt) had toxic effects, virtually eliminating germination. A thermoperiod of 10-25°C was the best treatment compared to 5-10°C. Dormancy was not a problem. While this plant is widely adapted, its intolerance to brackish and salt water limits its use in marsh habitat development to freshwater sites. Seed handling problems also exist and would likely hamper sowing operations.

Tufted Hairgrass

81. Tufted hairgrass is a coastal clump-forming grass in high fresh/brackish marshes from Alaska to California. It does not tolerate long periods of inundation. Stems can be 60-120 cm in height, with 0.7-m blades and 0.3-m purple-tinged seed heads. Seeds are quite small and are collected by gathering seed heads and shattering them. Plants flower in May and June and seeds mature in July through September. These studies showed that seeds germinated readily and that no pretreatment was required. Seeds germinated readily at 10-25°C but not at 5-10°C until after soaking in water 90 and 180 days. Brackish water storage slowed germination and salt water storage greatly reduced germination percentage, indicating limited salinity tolerance for this species. At 35 ppt salt solution practically no germination occurred at 5-10°C. Germination was reduced in 35 ppt salt solution and showed some toxic effects. This species is widely adapted to high marshes and can best be utilized in fresh/brackish areas with minimum prolonged inundation. Seed can be readily collected and threshed, and safely stored dry or in water for 180-day periods.

Big Cordgrass

82. Big cordgrass occurs in Atlantic and Gulf coastal fresh/

brackish marshes. True to its name, it often grows 3 to 4 m high with blades 2.5 to 3 cm across. Seed heads are large and multi-branched. It will tolerate inundation and brackish waters, but not extended highly saline conditions. Seeds are easily gathered by cutting seed heads and shattering them. Results of these studies show that dry storage slowed the seed germination rates but did not reduce viability. The thermoperiod of 10-25°C produced better initial seed germination than 20-35°C. After soaking in distilled water or salt solutions (10 ppt and 35 ppt), germination was faster than in dry storage. This species is suitable for marsh establishment. Big cordgrass can be propagated from seeds, and seeds can be stored wet up to 180 days.

Marsh Elder

83. Marsh elder is a perennial shrub that occurs in brackish/high salt marsh coastal areas. Its range extends along the entire United States Atlantic and Gulf coasts. Marsh elder may reach a height of 4 to 5 m. Seeds appearing along the outer branch tips are quite small. They are gathered in season (July to September) by picking seeds from branches of the shrub. The seeds are difficult to harvest in quantity and low viability is often encountered. The species is tolerant to high salt concentrations, with no toxic effects although osmotic inhibition may occur. The inhibition can be overcome by rinsing seeds in distilled water before germinating them. Results indicated the best seed germination thermoperiod for this species was 10-25°C compared to 20-35°C. Dry storage did not affect viability when seeds were germinated at optimum temperature. Storage in water produced satisfactory seed germination but brackish and salt water solutions considerably reduced germination percentages and rate. This high marsh species can be included in marshland vegetation programs using direct seed planting. Storage of 180 days is possible.

Saltmeadow Cordgrass

84. Saltmeadow cordgrass occurs in coastal brackish marshes on

the Atlantic and Gulf coasts, and on sand dunes and dikes on the Atlantic coast. It will tolerate inundation and brackish water, but not high salinities, and occurs in pure stands in large flooded areas, especially along the Gulf. Plants are 0.5 to 1 m high with very slender leaf blades. Seed heads are slender panicles. Seeds are readily gathered by collecting seed heads (September to October) and shattering them manually. Results indicated considerable dormancy that was not overcome by storage conditions. Neither 10-25°C or 20-35°C temperature regimes produced much seed germination, suggesting low viability of the seed and prolonged dormancy. Neither dry storage nor storage in water or salt solutions overcame dormancy.

Sea Ox-eye

85. Sea ox-eye is a salt marsh composite occurring along the Atlantic and Gulf coasts from Virginia to Texas. It is a woody, multi-branched shrub from 20 to 100 cm high, with fleshy gray-green leaves. Seeds usually mature in August and can be harvested in mid-September to early October by gathering seed heads and shattering them. The results of the study tests showed that seeds may be stored dry or wet, in fresh or brackish (10 ppt) water with small differences in total percent germination. However, storage in water produced faster germination than dry storage. This does not appear to be an indication of dormancy; rather, it would seem to be the result of the levels of moisture available to the seeds. Germination results were best at the 10-25°C thermoperiod compared to 20-35°C indicating the cooler requirements necessary for germination of this species. There apparently is no requirement of storage to break dormancy of the seeds, as those tested immediately upon receipt germinated readily. It appears that salinity affects germination and growth because in the 10 ppt salt solution, seeds were slow to germinate and seedlings grew slower than in distilled water. At a 35 ppt salt solution, no germination took place except after soaking 180 days, indicating osmotic inhibition. Given the results of this study, it appears that sea ox-eye, with its readily germinable seed, would be of

use in a marsh establishment plan. Its life requirements of elevation, inundation, and salinity, place it as a high marsh shrub. Seed should be obtained in season, and can be stored at least 180 days without affecting viability.

Smooth Cordgrass

86. Smooth cordgrass occurs in coastal salt marshes throughout the Atlantic and Gulf coasts. It has been introduced to the Pacific coast in past years. More research with smooth cordgrass seeds has been conducted than with any other marsh species, possibly because it is a pioneer species in tidal marshes and in disturbed intertidal areas. Two growth forms, short and tall, occur and are sometimes mistaken for two distinct species. Heights range from 0.2 to 2 m. Seed heads are often 0.3 to 0.5 m long, with clusters of seed on spikes. This species will tolerate many hours of tidal inundation and high salinities and is often the only plant occurring close to the water's edge. Seeds are collected by cutting seed heads in season (August to October) and shattering the seeds out. Seeds must be stored in seawater to remain viable. Care must be taken to collect clean seed heads free from fungus that commonly infects smooth cordgrass in all localities. This fungus can destroy viability. Dormancy was a problem and was not overcome by the study treatments. Seed germinated similarly at both 10-25°C and 20-35°C thermoperiods. Smooth cordgrass did not show any toxic effects from salt water solutions up to 180 days in storage. Due to wide adaptablity, high salinity tolerance, and readily available seeds, this species can be used for direct seeding of marsh sites with suitable substrates, taking into consideration the possible dormancy in fresh harvested seeds.

PART VI: CONCLUSIONS

87. Direct seeding offers a viable method for establishing certain species of marsh plants on dredged material as well as on natural marsh substrate. Seeds also provide a source of propagation for transplants and may be useful to nursery operations providing such transplants.

88. The unique environmental conditions encountered in marshes present ecological factors that differ considerably from uplant plants in terms of seed development, retention of viability, dormant periods, and conditions under which germination will occur. These factors are important in terms of collecting mature seeds, determining seed viability potential, pretreating to overcome seed dormancy, and germinating under suitable conditions to obtain prompt maximum seed germination.

89. Techniques for determining potential viability and dormancy were best accomplished by means of tetrazolium staining. Treatments used for each species have been determined by trial and error methods using established methods for similar species when possible. Germination often requires pretreatment, including cold temperature imbibition followed by suitable thermoperiods and photoperiods.

90. Plants included in this study represent species considered to be best suited for marsh establishment. Viable seeds for marsh establishment can be obtained by judicious collection at the proper stages of maturation and by storing seeds in solutions, such as distilled water or brackish water at low temperatures to both prolong viability and to overcome dormancy. After storage, rapid transit to planting sites is necessary to minimize germination prior to actual planting.

91. These results provide some indication of marsh plant species seed viability, dormancy, storage potential, and suitability for direct seeding. Table 29 outlines optimum storage conditions, thermoperiods, and duration periods for germinating these seeds. The report provides information for persons interested in seed collection, marsh seeding, growing transplants, and related research.

92. Problems encountered in obtaining maximum germination of some species, and the resultant promotion of germination by certain gases and

growth regulators, indicated a need for further study to ascertain the cause(s) of dormancy and the most suitable methods for obtaining germination. Such studies should include periodic seed collection during the maturation period and collection over several years to determine seasonal variation in dormancy and viability. Salinity, encountered during seed growth and maturation, storage in the natural environment, and in the imbibition treatment, presents a special aspect of dealing with marsh plants. Saline conditions may preclude seed germination through osmotic inhibition or destroy viability due to toxic concentrations. Seeds of salt marsh plants have various degrees of tolerance to salinity, enabling them to survive for long periods of time and then to germinate when saline conditions are abated by dilution or replacement with freshwater. Salt solutions appear to have a beneficial effect in controlling deleterious surface organisms on the seed and may have some dormancy abatement properties. Dormancy probably was the reason for nongermination of some seed, but this was not proven and may have resulted from other undetermined causes such as handling, the sorting of viable seeds, or individual treatment.

93. Other problems include removal of infertile seed units and other extraneous material in order to obtain maximum numbers of viable seeds. Such conditions would also present problems in evaluating seed quality for planting purposes. Seeds may be prepared by initial sieving in appropriate mesh screens followed by blowing in commercial seed blowers that separate heavy and light fractions. Very small seeds may require special vacuum counting aparatus for counting and for germination tests.

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Table 1

Initial seed germination and viability of selected marsh species studied

Species	Initial Germination[a]	Viability[b]
	%	%
Borrichia frutescens (sea ox-eye)	71	67
Carex lyngbyei (Lyngby's sedge)	50[c]	68
Carex obnupta (slough sedge)	63	61
Deschampia caespitosa (tufted hair-grass)	83	83
Iva frutescens (marsh elder)	49[c]	66
Juncus effusus (soft rush)	64	62
Salicornia pacifica (woody glass-wort)	92	79
Sagittaria latifolia (broadleaf arrowhead)	1[c]	52
Scirpus validus (tule)	1[c]	80
Spartina alterniflora (smooth cordgrass)	45[c]	94
Spartina cynosuroides (big cord-grass)	65	79
Spartina foliosa (Pacific cordgrass)	44[c]	81
Spartina patens (saltmeadow cord-grass)	7[c]	47

[a] See appropriate figure for germination regimes. Seeds were tested when received.

[b] Strong stain in 1% triphenyl tetrazolium chloride solution.

[c] Results due to dormancy.

Table 2

Germination of Borrichia frutescens at 10-25 and 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 days			Dry - 90 days	Soaked - 90 days[b]			Dry - 180 days	Soaked - 180 days[b]		
		Germination in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
1	10-25	0	0	0	0	0	0	0	10	60	48	18
2	10-25	18	1	0	0	66	55	0	44	70	77	56
3	10-25	30	3	0	39	66	54	0	65[c]	71	77	58
4	10-25	71	52	0	59	66	59	0		71[c]	78[c]	61[c]
5	10-25	--	--	--	66[c]	66[c]	69[c]	0[c]				
6	10-25	75[c]	72[c]	0[c]								
1	20-35	0	0	0	0	52	0	0	0	31	41	22
2	20-35	5	0	0	2	62	47	0	2	45	46	27
3	20-35	13	2	0	5	62	49	0	39	51	53	35
4	20-35	16	3	0	5	62	50	0	44	54[c]	55	38
5	20-35	--	--	--	7	62[c]	50	0	50		55[c]	39[c]
6	20-35	26[c]	8[c]	0[c]	11		50	0[c]	63[c]			
8	20-35				22[c]		51[c]					

[a] Average of four - 100 replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 3

Analysis of effects of storage, salt solution, and temperature on germination of Borrichia frutescens

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
10 ppt salt	180	10-25	78	A[a]
H_2O	0	10-25	75	A B
10 ppt salt	0	10-25	72	A B
H_2O	180	10-25	71	A B
10 ppt salt	90	10-25	69	B C
H_2O	90	10-25	66	B C
Stored dry	90	10-25	66	B C
Stored dry	180	10-25	65	B C D
Stored dry	180	20-35	63	B C D
H_2O	90	20-35	62	B C D
35 ppt salt	180	10-25	61	B C D
10 ppt salt	180	20-35	55	C D
H_2O	180	20-35	54	C D
10 ppt salt	90	20-35	51	C D
35 ppt salt	180	20-35	39	E
H_2O	0	20-35	26	F
Stored dry	90	20-35	22	F
10 ppt salt	0	20-35	8	G
35 ppt salt	90	20-35	0	G
35 ppt salt	0	10-25	0	G
35 ppt salt	90	10-25	0	G
35 ppt salt	0	20-35	0	G

[a] Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 4

Germination of Carex lyngbyei at 5-10 and 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germination in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
0	10-25	0	0	0	0	0	0	0	0	5	0	0
2	10-25	9	0	0	0	74	19	0	0	80	77	35
3	10-25	27	8	0	0	77	31	0	0	80	86	77
4	10-25	42	25	0	43	88	84	0	50	84	86[c]	77[c]
5	10-25	47	34	0	50	88	87	0	57	84[c]		
6	10-25	50[c]	40[c]	0[c]	53	88[c]	88	0	57			
7	10-25				54		89[c]	0[c]	66[c]			
8	10-25				69							
9	10-25				72[c]							
4	5-10	0	0	0	0	26	0	0	0	53	24	0
5	5-10	0	0	0	0	49	0	0	0	66	42	3
6	5-10	7	0	0	0	65	4	0	0	--	--	--
7	5-10	7	0	0	11	77	13	0	5[c]	75[c]	62[c]	12[c]
8	5-10	7	0	0	22	80	22	0				
9	5-10	7[c]	0[c]	0[c]	--	--	--	--				
12	5-10				49[c]	82[c]	34[c]	0[c]				

[a] Average of four - 100 replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 5

Analysis of effects of storage, salt solution, and temperature on germination of Carex lyngbyei

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
10 ppt salt	90	10-25	89	A[a]
H_2O	90	10-25	88	A
10 ppt salt	180	10-25	86	A
H_2O	180	10-25	84	A
H_2O	90	5-10	82	AB
35 ppt salt	180	10-25	77	ABC
H_2O	180	5-10	75	ABC
Stored dry	90	10-25	72	ABC
Stored dry	180	10-25	66	BCD
10 ppt salt	180	5-10	62	CDE
H_2O	0	10-25	50	DEF
Stored dry	90	5-10	49	EF
10 ppt salt	0	10-25	40	FG
10 ppt salt	90	5-10	34	G
35 ppt salt	180	5-10	12	H
H_2O	0	5-10	7	H
Stored dry	180	5-10	5	HI
35 ppt salt	0	5-10	0	I
35 ppt salt	0	10-25	0	I
35 ppt salt	90	10-25	0	I
10 ppt salt	0	5-10	0	I
35 ppt salt	90	5-10	0	I

[a] Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 6

Germination of Carex obnupta at 5-10 and 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germination in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
1	10-25	5	0	0	17	73	0	0				
2	10-25	23	0	0	39	92	0	0	7	84	85	25
4	10-25	36	2	0	45	94[c]	23	0	28	90	94[c]	60
5	10-25	50	8	0	50		--	0	53	91[c]		72
6	10-25	--	--	--	55		34	0	59			74
7	10-25	--	--	--	--		36	0	63[c]			76[c]
8	10-25	62	30	0	58[c]		37	0				
9	10-25	63[c]	35[c]	0[c]			38[c]	0[c]				
4	5-10	0	0	0	0	41	0	0	0	0	0	0
6	5-10	0	0	0	0	70[c]	0	0	0	0	0	0
12	5-10	0[c]	0[c]	0[c]	0[c]		0[c]	0[c]	0[c]	44[c]	15[c]	1[c]

[a] Average of four - 100 replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 7

Analysis of effects of storage, salt solution, and temperature on germination of *Carex obnupta*

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
10 ppt salt	180	10-25	94	A[a]
H_2O	90	10-25	94	A
H_2O	180	10-25	91	A
35 ppt salt	180	10-25	76	B
H_2O	90	5-10	70	B
H_2O	0	10-25	63	C
Stored dry	180	10-25	63	C
Stored dry	90	10-25	58	C
H_2O	180	5-10	44	D
10 ppt salt	90	10-25	38	D
10 ppt salt	0	10-25	35	D
10 ppt salt	180	5-10	15	E
10 ppt salt	90	5-10	0	F
35 ppt salt	0	10-25	0	F
35 ppt salt	90	10-25	0	F
H_2O	0	5-10	0	F
10 ppt salt	0	5-10	0	F
35 ppt salt	0	5-10	0	F
Stored dry	90	5-10	0	F
35 ppt salt	90	5-10	0	F
Stored dry	180	5-10	0	F
35 ppt salt	180	5-10	1	F

[a] Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 8

Germination of *Deschampsia caespitosa* at 5-10 and 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germination in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	
1	10-25	37	4	0	2	21	0	0	85			
2	10-25	83	82	0	87	91	62	0	94			65
3	10-25	83[c]	82[c]	0[c]	90	91	67	0	94[c]			68[c]
4	10-25				90	91[c]	68[c]	0[c]				
5	10-25				91[c]							
2	5-10	0	0	0	0	0	0	1	5	87	49	0
3	5-10	0	0	0	0	0	0	1	18	90[c]	59	11
5	5-10	0	0	0	2	42	9	1	18		59	11
6	5-10	0	0	0	3	69	13	1	18		59	11
7	5-10	0	0	0	3[c]	79	13[c]	1[c]	18		59	11
8	5-10	0	0	0		80[c]			18		59	11
12	5-10	0[c]	0[c]	0[c]					19[c]		74[c]	41[c]

[a] Average of four - 100 replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 9

Analysis of effects of storage, salt solution, and temperature on germination of Deschampsia caespitosa

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
H_2O	180	10-25	96	A[a]
10 ppt salt	180	10-25	94	A B
Stored dry	180	10-25	94	A B
H_2O	90	10-25	91	A B
Stored dry	90	10-25	91	A B
H_2O	180	5-10	90	A B
H_2O	90	5-10	80	B C
10 ppt salt	0	10-25	82	C
10 ppt salt	180	5-10	74	C
35 ppt salt	180	10-25	68	C
10 ppt salt	90	10-25	68	C
35 ppt salt	180	5-10	41	D
Stored dry	180	5-10	19	E
10 ppt salt	90	5-10	13	EF
Stored dry	90	5-10	3	G
35 ppt salt	90	5-10	1	G
35 ppt salt	0	5-10	0	G
H_2O	0	10-25	0	G
35 ppt salt	0	10-25	0	G
35 ppt salt	90	10-25	0	G
H_2O	0	5-10	0	G
10 ppt salt	0	5-10	0	G

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 10

Germination of Iva frutescens at 10-25 and 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 days	Soaked - 180 Days[b]		
		Germ. in in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
1	10-25	34	5	0	0	45	18	0	0	47	21	27
2	10-25	37	14	0	37	47	29	0	43	48	22	38
3	10-25	--	--	--	48	49	29[c]	0	43	56[c]	22[c]	39
4	10-25	--	--	--	48[c]	49[c]		2	48[c]			40[c]
5	10-25	49[c]	17[c]	0[c]				4[c]				
1	20-35	0	0	0	0	46	22	0	0	43	52	15
2	20-35	0	0	0	2	46[c]	28	0	0[c]	43[c]	52[c]	16[c]
3	20-35	0[c]	0[c]	0[c]	3[c]		28[c]	0[c]				

[a] Average of four - 100 replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 11

Analysis of effects of storage, salt solution, and temperature on germination of Iva frutescens

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
H_2O	180	10-25	56	A[a]
10 ppt salt	180	20-35	52	AB
H_2O	0	10-25	49	AB
H_2O	90	10-25	49	AB
Stored dry	180	10-25	48	AB
Stored dry	90	10-25	48	AB
H_2O	90	20-35	46	AB
H_2O	180	20-35	43	BC
35 ppt salt	180	10-25	40	C
10 ppt salt	90	10-25	29	CD
10 ppt salt	90	20-35	28	DE
10 ppt salt	180	10-25	22	EF
10 ppt salt	0	10-25	17	F
35 ppt salt	180	20-35	16	F
35 ppt salt	90	10-25	4	G
Stored dry	90	20-35	3	G
35 ppt salt	0	10-25	0	G
H_2O	0	20-35	0	G
10 ppt salt	0	20-35	0	G
35 ppt salt	0	20-35	0	G
35 ppt salt	90	20-35	0	G
Stored dry	180	20-35	0	G

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 12

Germination of Juncus effusus at 5-10 and 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germ. in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
1	10-25								0	46	6	0
2	10-25	41	18	0	25	76	--	--	59	76[c]	32	1
3	10-25	44	28	0	51	81	47	16	72		44	3[c]
4	10-25	53	39	0	77	85	57	31	74		44	
5	10-25	59	47	0	87	87[c]	62[c]	36[c]	76[c]		47[c]	
6	10-25	64[c]	61[c]	0[c]	88[c]							
1	5-10								0	0	0	0
2	5-10								0	0	0	0
3	5-10								0	0	0	0
4	5-10								0	4	0	0
5	5-10								0[c]	21[c]	0[c]	0[c]
7	5-10	0	0	0	0	9	0	0				
8	5-10	0[c]	0[c]	0[c]	0[c]	35[c]	5[c]	0[c]				

[a] Average four - 100 seed replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 13

Analysis of effects of storage, salt solution, and temperature on germination of Juncus effusus

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
Stored dry	90	10-25	88	A[a]
H_2O	90	10-25	87	A
Stored dry	180	10-25	76	B
H_2O	180	10-25	76	B
H_2O	0	10-25	64	C
10 ppt salt	90	10-25	62	C
10 ppt salt	0	10-25	61	C
10 ppt salt	180	10-25	47	D
35 ppt salt	90	10-25	36	D
H_2O	90	5-10	35	D
H_2O	180	5-10	21	E
10 ppt salt	90	5-10	5	F
35 ppt salt	180	10-25	3	F
H_2O	0	5-10	0	F
10 ppt salt	0	5-10	0	F
35 ppt salt	0	5-10	0	F
Stored dry	180	5-10	0	F
10 ppt salt	180	5-10	0	F
35 ppt salt	180	5-10	0	F
35 ppt salt	0	10-25	0	F
Stored dry	90	5-10	0	F
35 ppt salt	90	5-10	0	F

[a] Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 14

Germination of Sagittaria latifolia at 10-25 and at 30°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germ. in in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
2	10-25	0	0	0	0	0	0	0	0	36	10	0
3	10-25	0	0	0	11	26	0	0	0	39	13	0
4	10-25	0	0	0	18	29	2	0	0	39[c]	14[c]	0[c]
5	10-25	0	0	0	21	33	7	0	0			
6	10-25	0[c]	0[c]	0[c]	21[c]	34[c]	7[c]	0[c]	0[c]			
1	30	0	0	0	0	26	0	0	0	25	10	0
2	30	0	0	0	2	30	0	0	0	25	10	0
3	30	0	0	0	3[c]	31[c]	0[c]	0[c]	0[c]	25[c]	10[c]	0[c]
4	30	0[c]	0[c]	0[c]								

[a] Average of four - 100 seed replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 15

Analysis of effects of storage, salt solution, and temperature on germination of *Sagittaria latifolia*

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
H_2O	180	10-25	39	A[a]
H_2O	90	10-25	34	A
H_2O	90	30	31	A
H_2O	180	30	25	B
Stored dry	90	10-25	21	B
10 ppt salt	180	10-25	14	C
10 ppt salt	180	30	10	C
10 ppt salt	90	10-25	7	C
Stored dry	90	30	3	C
10 ppt salt	90	30	0	D
Stored dry	180	30	0	D
H_2O	0	10-25	0	D
10 ppt salt	0	10-25	0	D
35 ppt salt	0	10-25	0	D
35 ppt salt	90	10-25	0	D
Stored dry	180	10-25	0	D
35 ppt salt	180	10-25	0	D
H_2O	0	30	0	D
10 ppt salt	0	30	0	D
35 ppt salt	0	30	0	D
35 ppt salt	90	30	0	D
35 ppt salt	180	30	0	D

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 16

Effects of gibberellin and kinetin in combination with ethylene and other gases on germination of Sagittaria latifolia[a]

	H_2O	Gibberellin	Kinetin	GA + Kinetin
	% Germination			
Control open	16	1	7.6	8
Control closed	10	10	14	10
Flushed with oxygen	0.5	0.5	0	1
Oxygen + 10 ppm ethylene	1.5	1	0.5	0.5
20% Carbon dioxide + 10 ppm Ethylene	36[b]	35.6[b]	35.6[b]	34[b]
20% Carbon dioxide	50[b]	31[b]	23.6[b]	39.6[b]
10 ppm Ethylene	33.6[b]	27.4[b]	34.6[b]	19[b]
Flushed with nitrogen	40[b]	36.6[b]	38[b]	34.6[b]

[a] Treatment of 10-25°C for 42 days.

[b] Treatment significantly different at the five percent level as compared to closed control.

Table 17

Germination of Salicornia pacifica at 5-10 and 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germ. in in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
1	10-25	66	54	20	21	88	51	88	25	84	12	41
2	10-25	92[c]	93[c]	66[c]	82	88[c]	51[c]	89	80	84	15	58
3	10-25				84[c]			91[c]	83	84[c]	16	61
4	10-25								83[c]		16[c]	66
5	10-25											69[c]
1	5-10	0	0	0	0	73	0	0	0	13	7	12
2	5-10	23	0	0	0	89	35	22	0	38	7	17
3	5-10	44	21	0	0	91	41	31	1	48	11	17
4	5-10	73[c]	40	14	11	91[c]	41[c]	33[c]	3	51	12	23
5	5-10		71[c]	--	38				5[c]	53[c]	12[c]	30[c]
8	5-10			24[c]	38[c]							

[a] Average of four - 100 replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 18

Analysis of effects of storage, salt solution, and temperature on germination of *Salicornia pacifica*

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
10 ppt salt	0	10-25	93	A[a]
H_2O	0	10-25	92	A
H_2O	90	5-10	91	A
35 ppt salt	90	10-25	91	A
H_2O	90	10-25	88	A B
H_2O	180	10-25	84	B
Stored dry	90	10-25	84	B
Stored dry	180	10-25	83	B
H_2O	0	5-10	73	C
10 ppt salt	0	5-10	71	C
35 ppt salt	180	10-25	69	C
35 ppt salt	0	10-25	66	C
H_2O	180	5-10	53	D
10 ppt salt	90	10-25	51	D
10 ppt salt	90	5-10	41	E
Stored dry	90	5-10	38	E
35 ppt salt	90	5-10	33	EF
35 ppt salt	180	5-10	30	F
35 ppt salt	0	5-10	24	F
10 ppt salt	180	10-25	16	G
10 ppt salt	180	5-10	12	G
Stored dry	180	5-10	5	H

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 19

Germination of Scirpus validus at 5-10 and 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germ. in in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
2	10-25	0	0	0	0	41	0	0	0	0	0	0
3	10-25	0	0	0	0	52	4	0	0	45	47	35
4	10-25	0	0	0	1	63	15	0	0	50	54	45
5	10-25	0	0	0	2	65	16	0	1	52	56	46
6	10-25	0	0	0	5	67	18	0	2	53	56	47
7	10-25	0[c]	0[c]	0[c]	7[c]	68[c]	18[c]	0[c]	2[c]	56[c]	58[c]	47[c]
	5-10	No germination was obtained for any treatments or storage conditions.										

[a] Average of four - 100 seed replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 20

Analysis of effects of storage, salt solution, and temperature on germination of Scirpus validus

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
H_2O	90	10-25	68	A[a]
10 ppt salt	180	10-25	58	B
H_2O	180	10-25	56	B
35 ppt salt	180	10-25	47	C
10 ppt salt	90	10-25	18	D
Stored dry	90	10-25	7	E
Stored dry	180	10-25	2	E
H_2O	0	10-25	0	E
10 ppt salt	0	10-25	0	E
35 ppt salt	0	10-25	0	E
35 ppt salt	0	10-25	0	E

[a] Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 21

Germination of Spartina alterniflora at 10-25 and 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germ. in in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
0	10-25	0	0	0	0	46	45	22	0	36	47	34
1	10-25	0	0	0	0	52	50	37	0	37	50	49
2	10-25	9	18	16	0	52	51	45	0	37[c]	50[c]	52
3	10-25	18	26	24	2	52	51	45	0			53[c]
4	10-25	18	26	24	2	52[c]	51[c]	45[c]	0[c]			
5	10-25	23[c]	29[c]	28[c]	2[c]							
0	20-35	0	0	0	0	41	48	21	0	39	50	15
1	20-35	0	0	0	0	49	56	57	0	42	64	55
2	20-35	36	38	25	2	49[c]	57	61	0	42[c]	64[c]	55[c]
3	20-35	45[c]	56[c]	59[c]	2		57[c]	67[c]	0[c]			
4	20-35				3[c]							

[a] Average of four - 100 seed replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 22

Analysis of effects of storage, salt solution, and temperature on germination of Spartina alterniflora

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
35 ppt salt	90	20-35	67	A[a]
10 ppt salt	180	20-35	64	A
35 ppt salt	0	20-35	59	A
10 ppt salt	90	20-35	57	AB
10 ppt salt	0	20-35	56	AB
35 ppt salt	180	20-35	55	AB
35 ppt salt	180	10-25	53	B
H_2O	90	10-25	52	B
10 ppt salt	90	10-25	51	B
10 ppt salt	180	10-25	50	B
H_2O	90	20-35	49	B
35 ppt salt	90	10-25	45	BC
H_2O	0	20-35	45	BC
H_2O	180	20-35	42	BC
H_2O	180	10-25	37	C
10 ppt salt	0	10-25	29	C
35 ppt salt	0	10-25	28	C
H_2O	0	10-25	23	CD
Stored dry	90	20-35	3	E
Stored dry	90	10-25	2	E
Stored dry	180	10-25	0	E
Stored dry	180	20-35	0	E

[a] Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 23

Germination of Spartina cynosuroides at 10-25 and 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germ. in in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
0	10-25	0	0	0	0	0	0	0	0	24	6	0
1	10-25	0	0	0	0	43	6	0	0	52	58	33
2	10-25	0	0	0	0	65	61	6	--	--	--	--
3	10-25	0	0	0	2	66	66	25	--	--	--	--
4	10-25	12	6	0	19	66[c]	66[c]	28	19	52[c]	58[c]	45
5	10-25	29	20	0	49			31	22			45[c]
6	10-25	56	53	19	57			31[c]	--			
7	10-25	60	57	34	57				23[c]			
8	10-25	--	--	--	58							
9	10-25	65[c]	61[c]	45[c]	58[c]							
0	20-35	0	0	0	0	0	0	0	0	16	6	0
1	20-35	0	0	0	0	56	49	0	0	50	57	46
2	20-35	0	0	0	0	62	63	18	2	51	60	47
3	20-35	2	1	0	4	62[c]	63[c]	37	15	51	60	47
4	20-35	4	2	0	7			39	--	51[c]	60[c]	47[c]
5	20-35	4	2	0	9			41	21[c]			
6	20-35	9	5	0	10			41[c]				
8	20-35	9[c]	5[c]	0[c]	15[c]							

[a] Average of four - 100 seed replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 24

Analysis of effects of storage, salt solution, and temperature on germination of Spartina cynosuroides

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
H_2O	0	10-25	65	A[a]
H_2O	90	20-35	62	A
10 ppt salt	90	20-35	63	A
10 ppt salt	90	10-25	66	A
10 ppt salt	0	10-25	61	A
H_2O	90	10-25	66	AB
10 ppt salt	180	20-35	60	ABC
Stored dry	90	10-25	58	ABC
10 ppt salt	180	10-25	58	ABC
35 ppt salt	0	10-25	45	BCD
H_2O	180	10-25	52	CD
H_2O	180	20-35	51	CD
35 ppt salt	180	20-35	47	CDE
35 ppt salt	180	10-25	45	CDE
35 ppt salt	90	20-35	41	CDE
35 ppt salt	90	10-25	31	F
Stored dry	180	10-25	23	G
Stored dry	180	20-35	21	G
Stored dry	90	20-35	15	H
H_2O	0	20-35	9	I
10 ppt salt	0	20-35	5	I
35 ppt salt	0	20-35	0	J

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 25

Germination of Spartina foliosa at 10-25 and 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

		Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
Germ. Time	Germ. Thermoperiod	Germ. in in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
0	10-25	0	0	0	0	0	0	0	0	46	23	9
1	10-25	0	0	0	0	32	19	4	0	47	33	30
2	10-25	38	32	24	0	40[c]	36[c]	37	--	--	--	--
3	10-25	41	35	35	0				0[c]	48[c]	33[c]	30[c]
4	10-25	43[c]	36	--	0							
5	10-25		37[c]	--	0							
6	10-25			43	0							
10	10-25			47[c]	0[c]							
0	20-35	0	0	0	0	0	0	0	0	43	29	35
1	20-35	6	5	0	0	0	0	0	0[c]	44[c]	35[c]	40[c]
2	20-35	44[c]	42[c]	30[c]	0	30	25	0				
3	20-35				0[c]	39[c]	45[c]	38[c]				

[a] Average of two - 100 replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 26

Analysis of effects of storage, salt solution, and temperature on germination of Spartina foliosa

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
H_2O	180	10-25	48	A[a]
35 ppt salt	0	10-25	47	A
H_2O	90	20-35	45	A
H_2O	0	20-35	44	A
H_2O	180	20-35	44	A
H_2O	0	10-25	43	A
10 ppt salt	0	10-25	42	A
35 ppt salt	180	20-35	40	A
H_2O	0	10-25	40	A
H_2O	90	20-35	39	A
35 ppt salt	90	20-35	38	A
10 ppt salt	0	10-25	37	B
35 ppt salt	90	10-25	37	B
10 ppt salt	90	10-25	36	B
10 ppt salt	180	20-35	35	B
10 ppt salt	180	10-25	33	B
35 ppt salt	180	10-25	30	B
35 ppt salt	0	20-35	30	B
Stored dry	90	10-25	0	C
Stored dry	180	10-25	0	C
Stored dry	90	20-35	0	C
Stored dry	180	20-35	0	C

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 27

Germination of Spartina patens at 10-25 and 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution[a]

Germ. Time	Germ. Thermoperiod	Soaked - 0 Days			Dry - 90 Days	Soaked - 90 Days[b]			Dry - 180 Days	Soaked - 180 Days[b]		
		Germ. in Dist. Water	Germ. in 10 ppt Salt	Germ. in 35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt	Germination in Dist. Water	Dist. Water	10 ppt Salt	35 ppt Salt
Weeks	°C	%	%	%	%	%	%	%	%	%	%	%
1	10-25	0	0	0	0	0	6	0	0	0	0	0
2	10-25	3	0	0	5	2	13	0	0	2	1	0
3	10-25	7[c]	4[c]	0[c]	9[c]	2[c]	15[c]	2[c]	0	4	1	0
4	10-25								0[c]	5[c]	4[c]	0[c]
1	20-35	0	0	0	0	9	3	0	0	5	8	0
2	20-35	0	0	0	0	12[c]	7	3	1[c]	6[c]	8[c]	7[c]
3	20-35	0	2	0	2		8[c]	3[c]				
4	20-35	2	2	0	2[c]							
5	20-35	4	2	0								
6	20-35	6[c]	4[c]	0[c]								

[a] Average four - 100 seed replications.

[b] Germinated in distilled water.

[c] Germination test terminated.

Table 28

Analysis of effects of storage, salt solution, and temperature on germination of *Spartina patens*

Treatment	Storage Days	Germination Thermoperiod °C	Germination %	Mean
10 ppt salt	90	10-25	15	A[a]
H_2O	90	20-35	12	A
Stored dry	90	10-25	9	B
10 ppt salt	90	20-35	8	B
10 ppt salt	180	20-35	8	B
H_2O	0	10-25	7	B
35 ppt salt	180	20-35	7	B
H_2O	0	20-35	6	B
H_2O	180	20-35	6	B
H_2O	180	10-25	5	B
10 ppt salt	0	10-25	4	B
10 ppt salt	0	20-35	4	B
10 ppt salt	180	10-25	4	B
35 ppt salt	90	20-35	3	B
Stored dry	90	20-35	2	B
H_2O	90	10-25	2	B
35 ppt salt	90	10-25	2	B
Stored dry	180	20-35	1	B
35 ppt salt	0	10-25	0	C
35 ppt salt	0	20-35	0	C
Stored dry	180	10-25	0	C
35 ppt salt	180	10-25	0	C

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's New Multiple Range Test.

Table 29

Optimum germination storage conditions, thermoperiods, and germination period for marshland species studied [a]

Species	Storage treatment/days	Thermoperiod °C	Germination Weeks	Maximum Percent Germination
Borrichia frutescens	SS-10[b]/180	10-25	4	78
Carex lyngbyei	SS-10/90	10-25	7	89
Carex obnupta	water/90	10-25	4	94
	SS-10/180	10-25	4	94
Deschampsia caespitosa	water/180	10-25	1	96
Iva frutescens	water/180	10-25	3	56
Juncus effusus	dry/90	10-25	6	88
Sagittaria latifolia	water/180	10-25	4	39
Salicornia pacifica	SS-10/0	10-25	2	93
Scirpus validus	water/90	10-25	7	68
Spartina alterniflora	SS-35/90	20-35	3	67
Spartina cynosuroides	water/90	10-25	4	66
	SS-10/90	10-25	4	66
Spartina foliosa	water/180	10-25	3	48
Spartina patens	SS-10/90	10-25	3	15

[a] Optimum conditions defined as those conditions where maximum percent germination occurred.

[b] Refers to salt solution in parts per thousand.

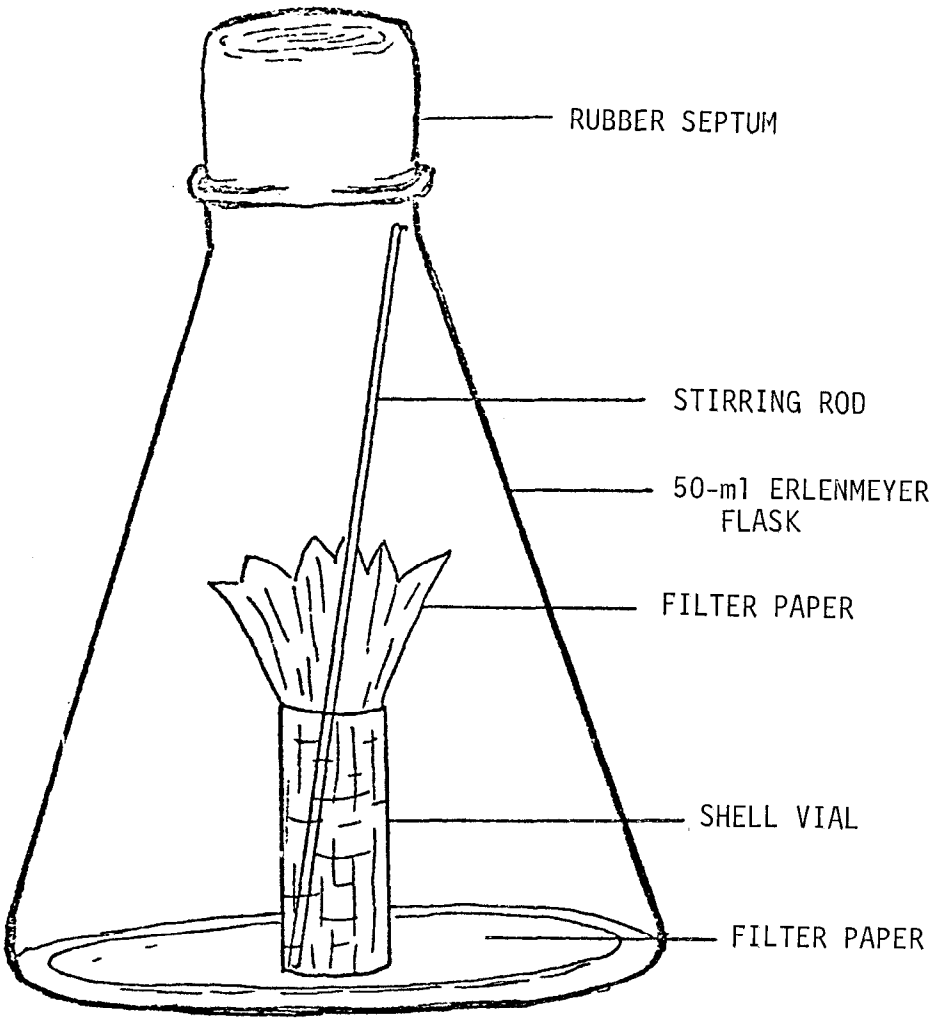

Figure 1. Flask apparatus for growth regulator and gaseous environment

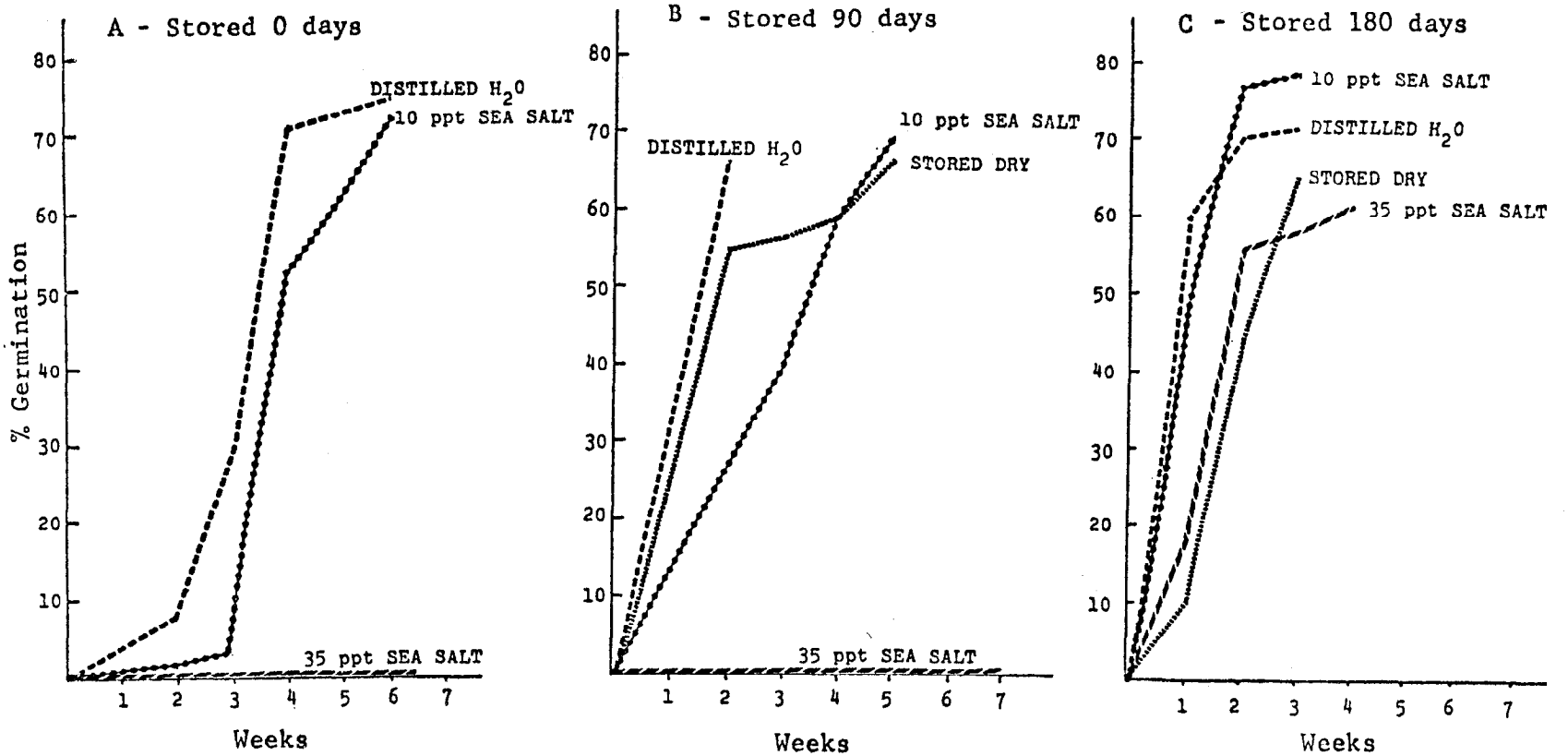

Figure 2. Germination of Borrichia frutescens at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

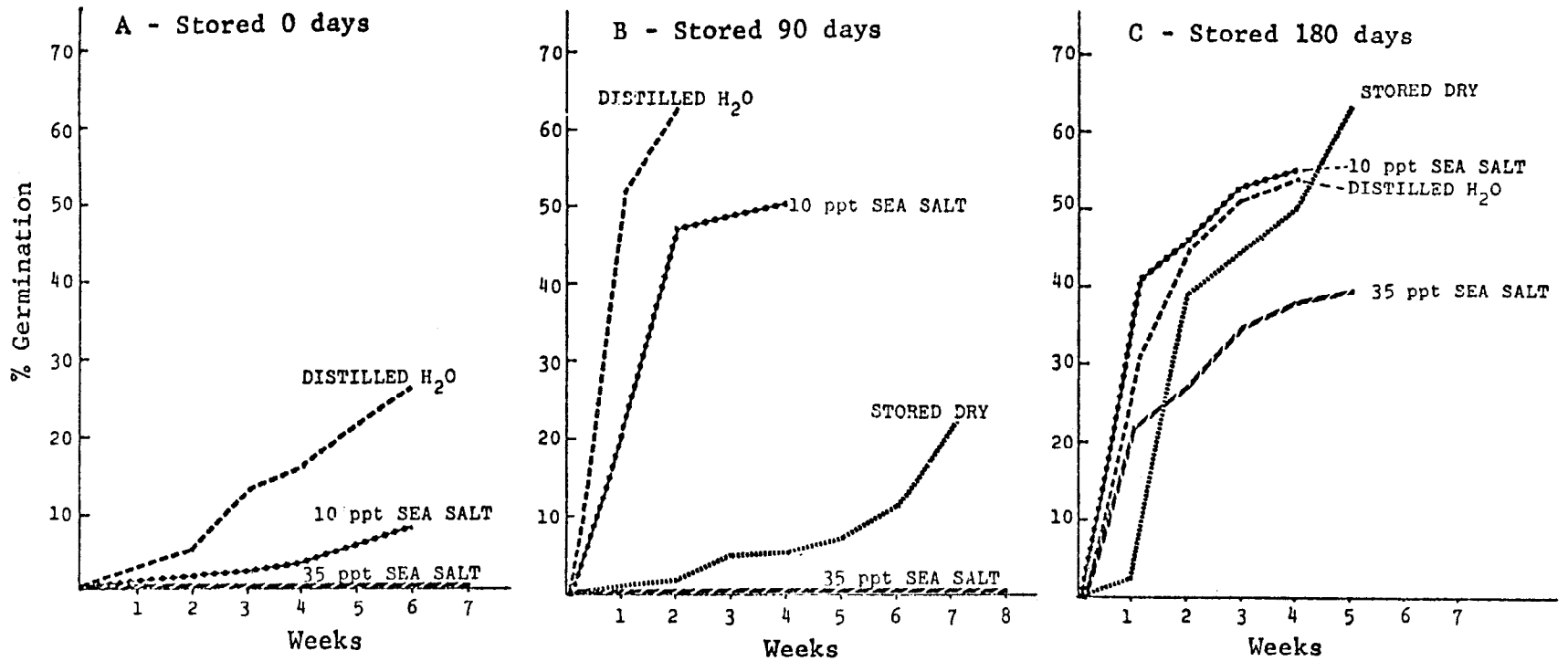

Figure 3. Germination of Borrichia frutescens at 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

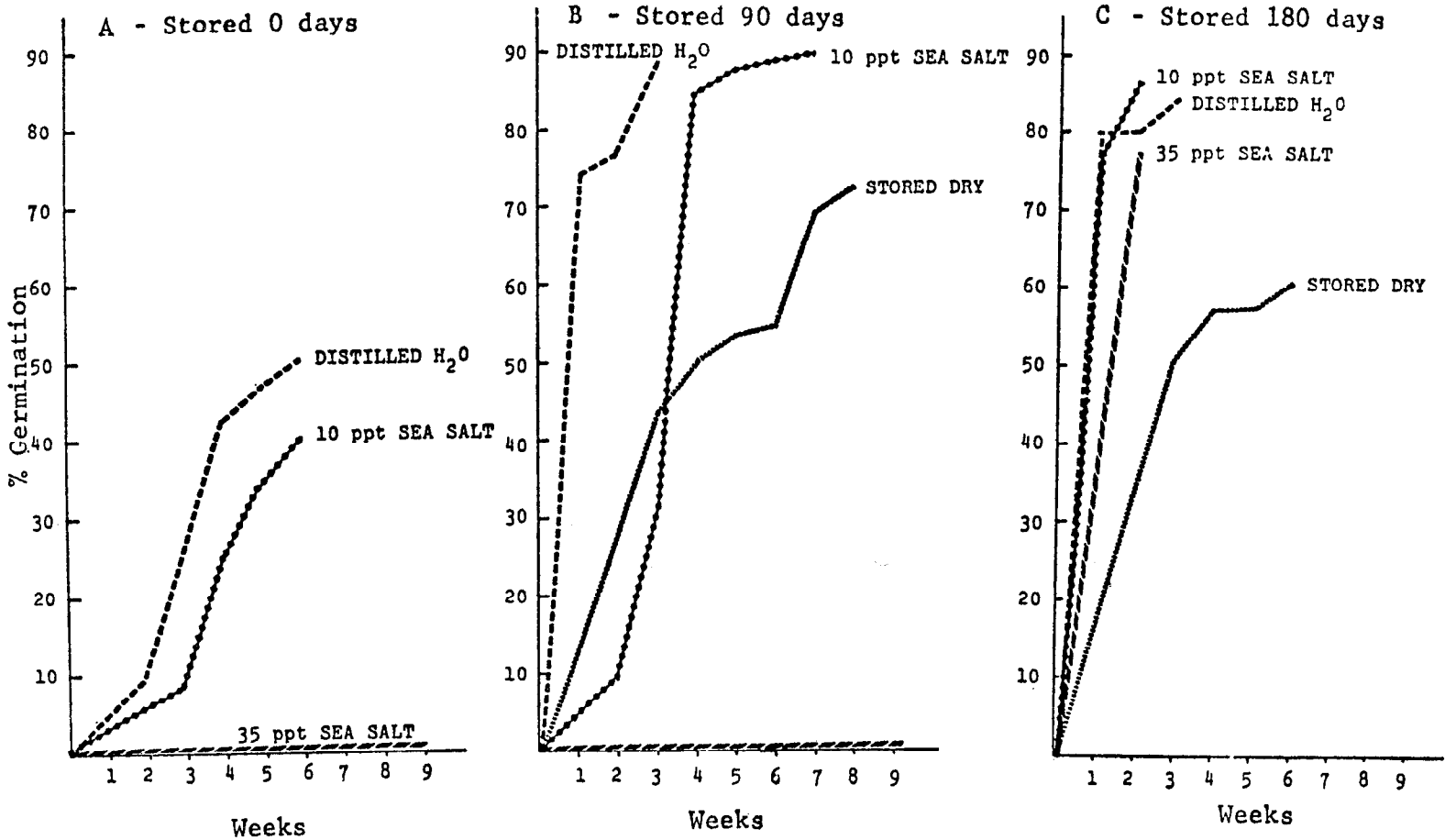

Figure 4. Germination of Carex lyngbyei at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

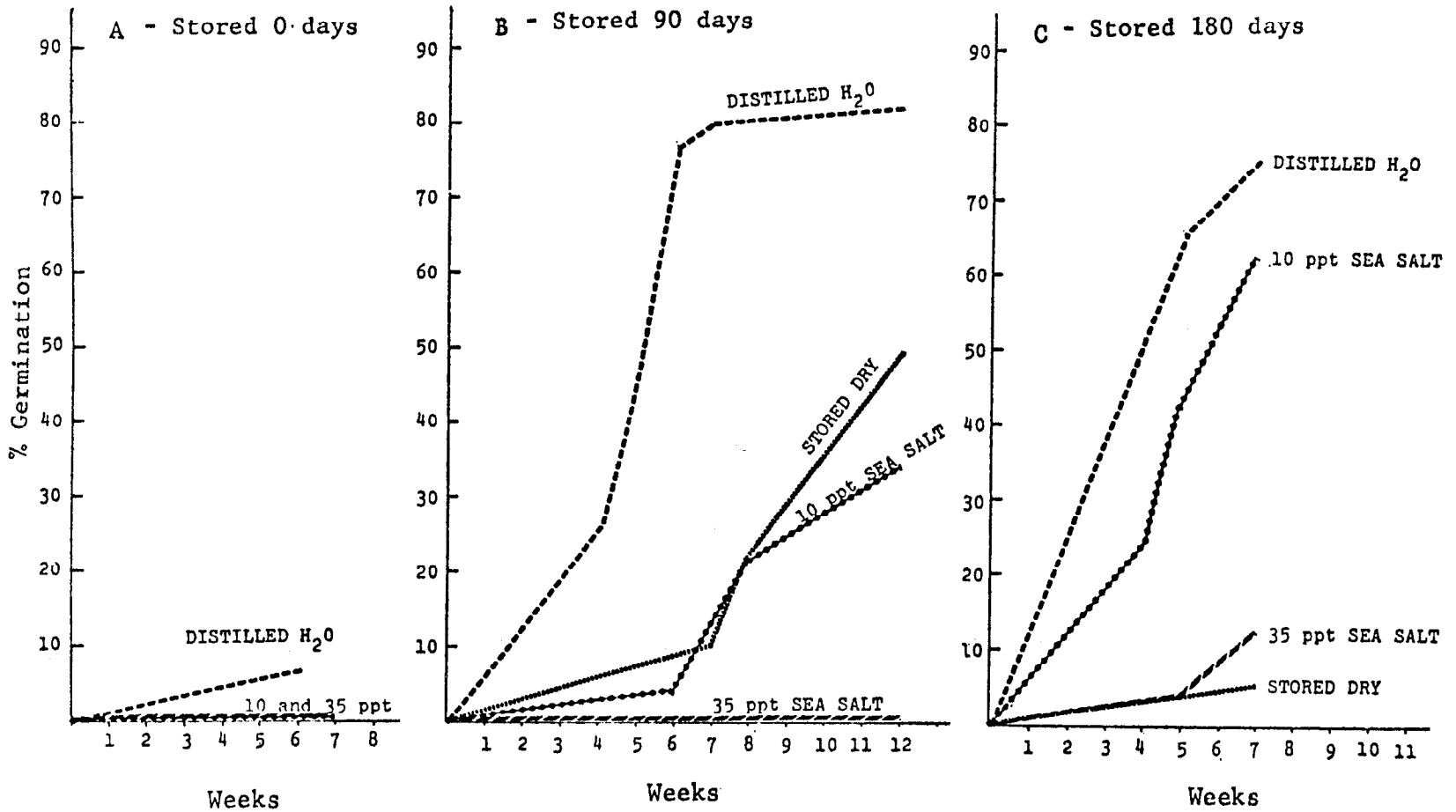

Figure 5. Germination of Carex lyngbyei at 5-10°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

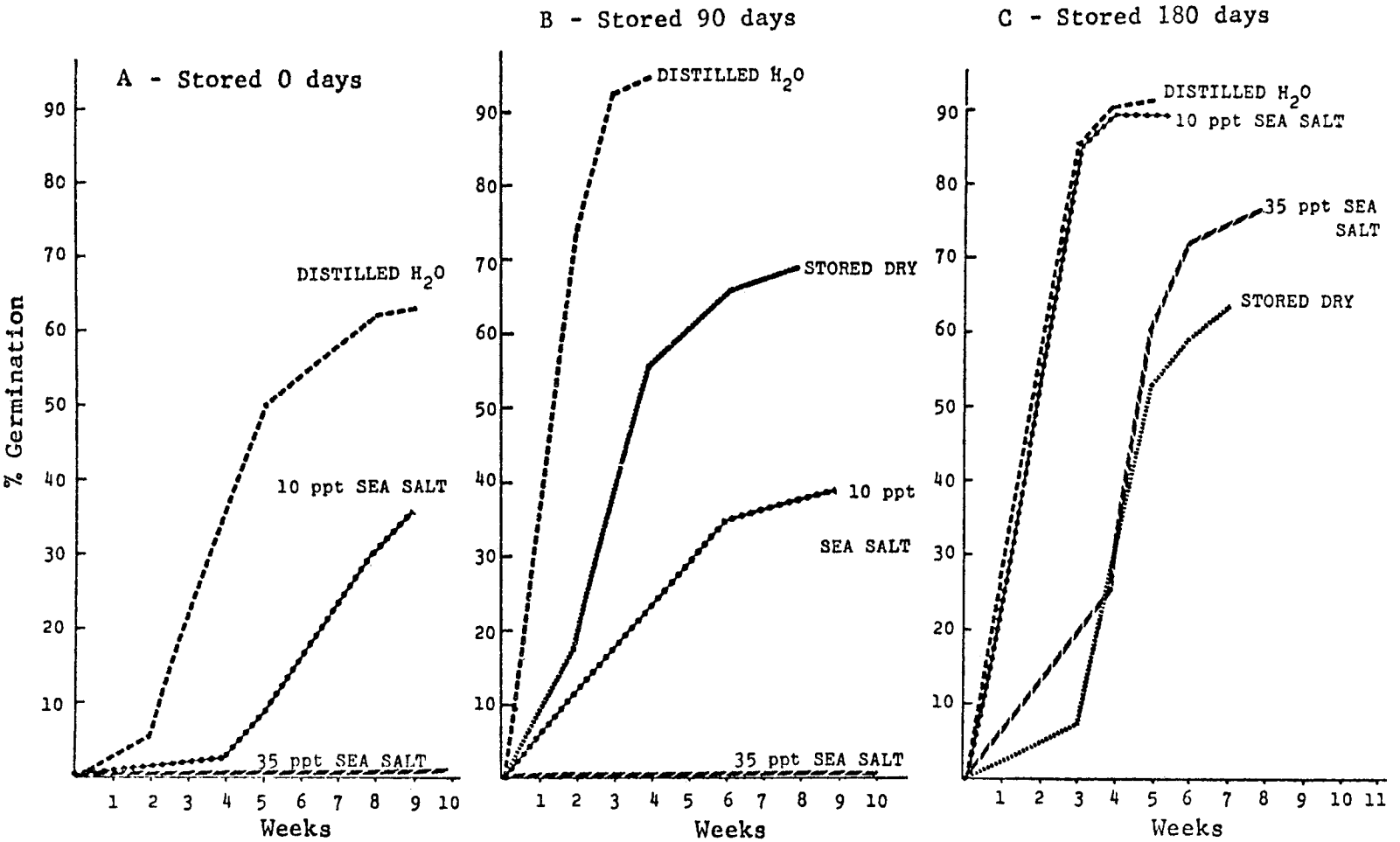

Figure 6. Germination of Carex obnupta at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

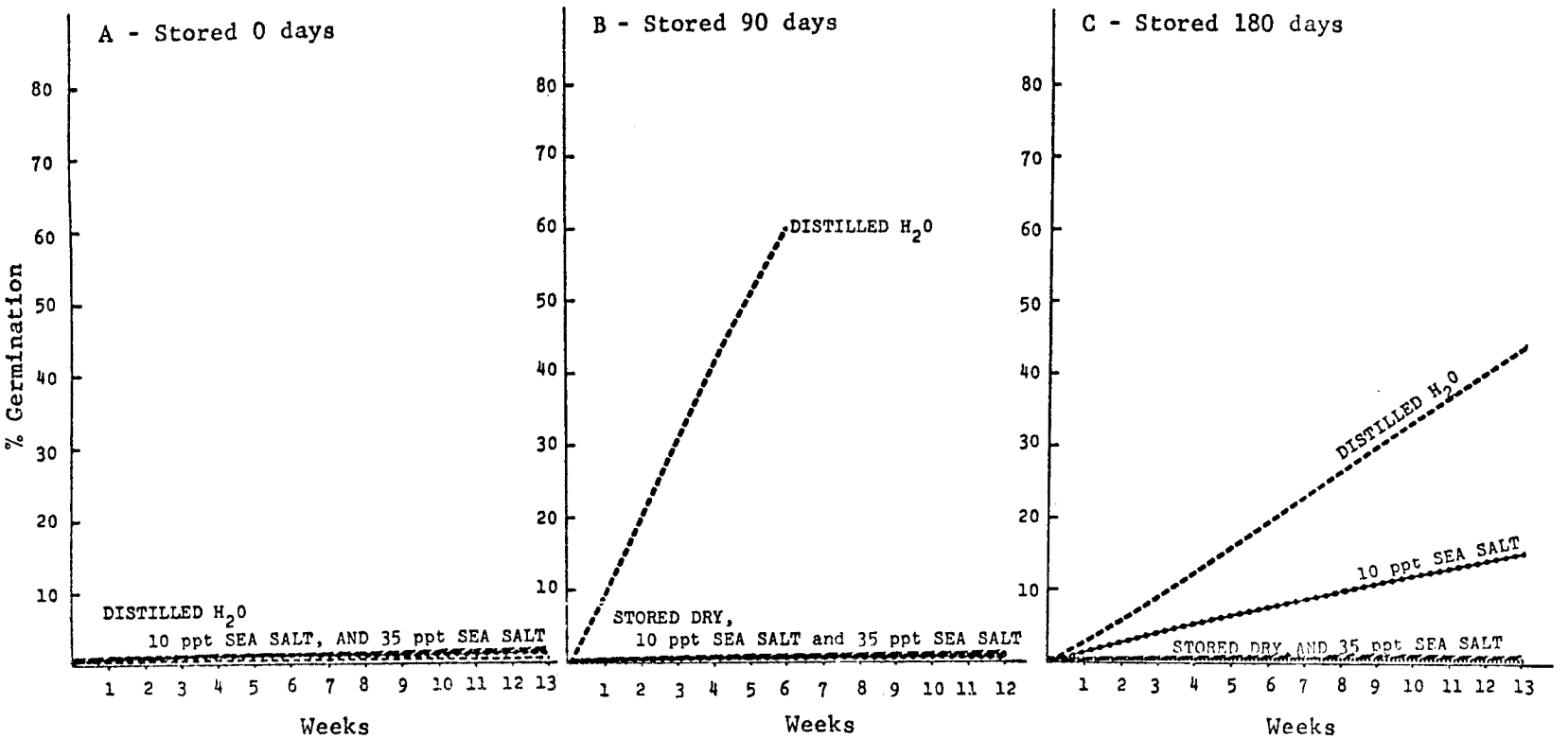

Figure 7. Germination of Carex obnupta at 5-10°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

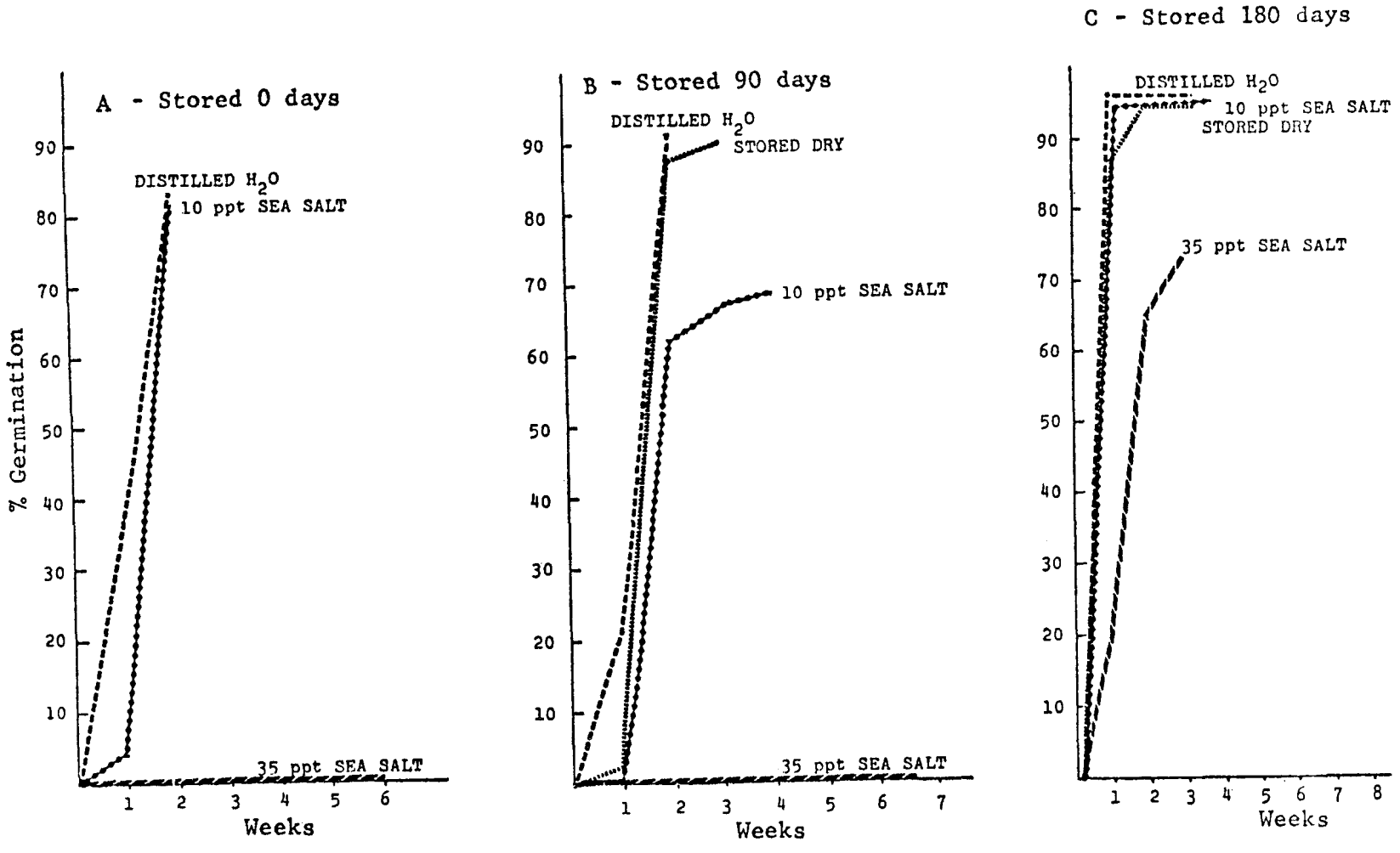

Figure 8. Germination of Deschampsia caespitosa at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

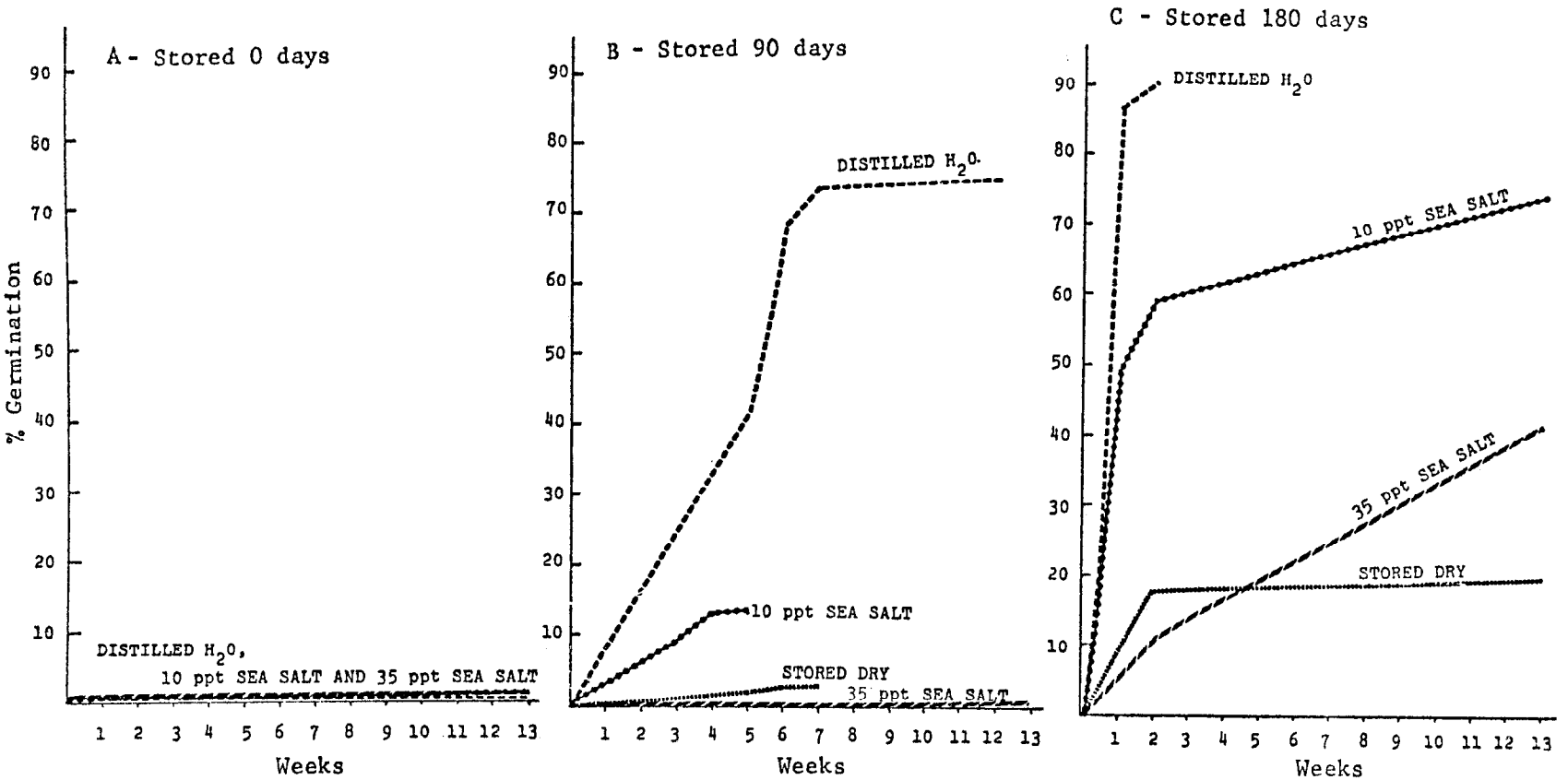

Figure 9. Germination of Deschampsia caespitosa at 5-10°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

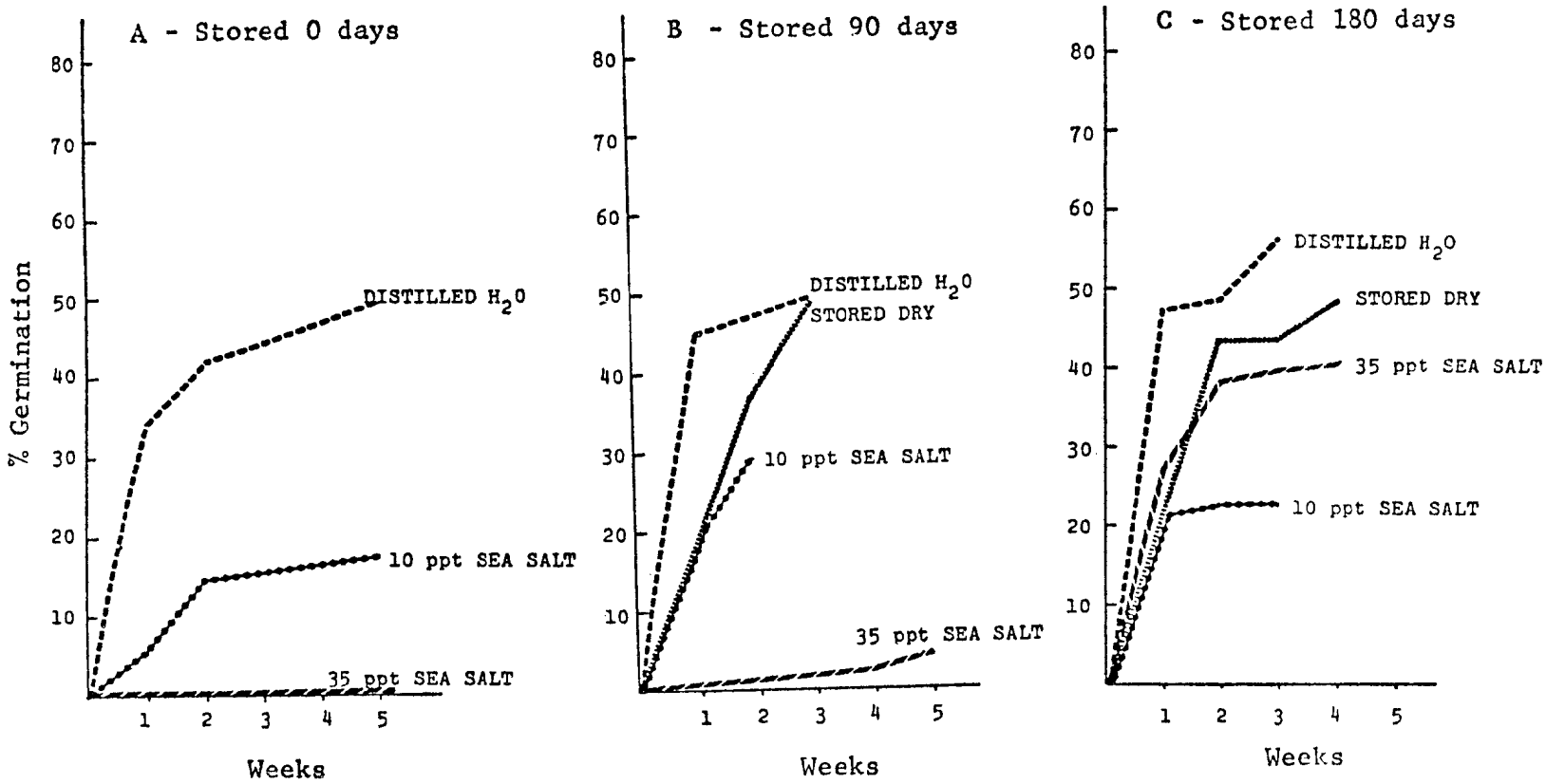

Figure 10. Germination of Iva frutescens at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

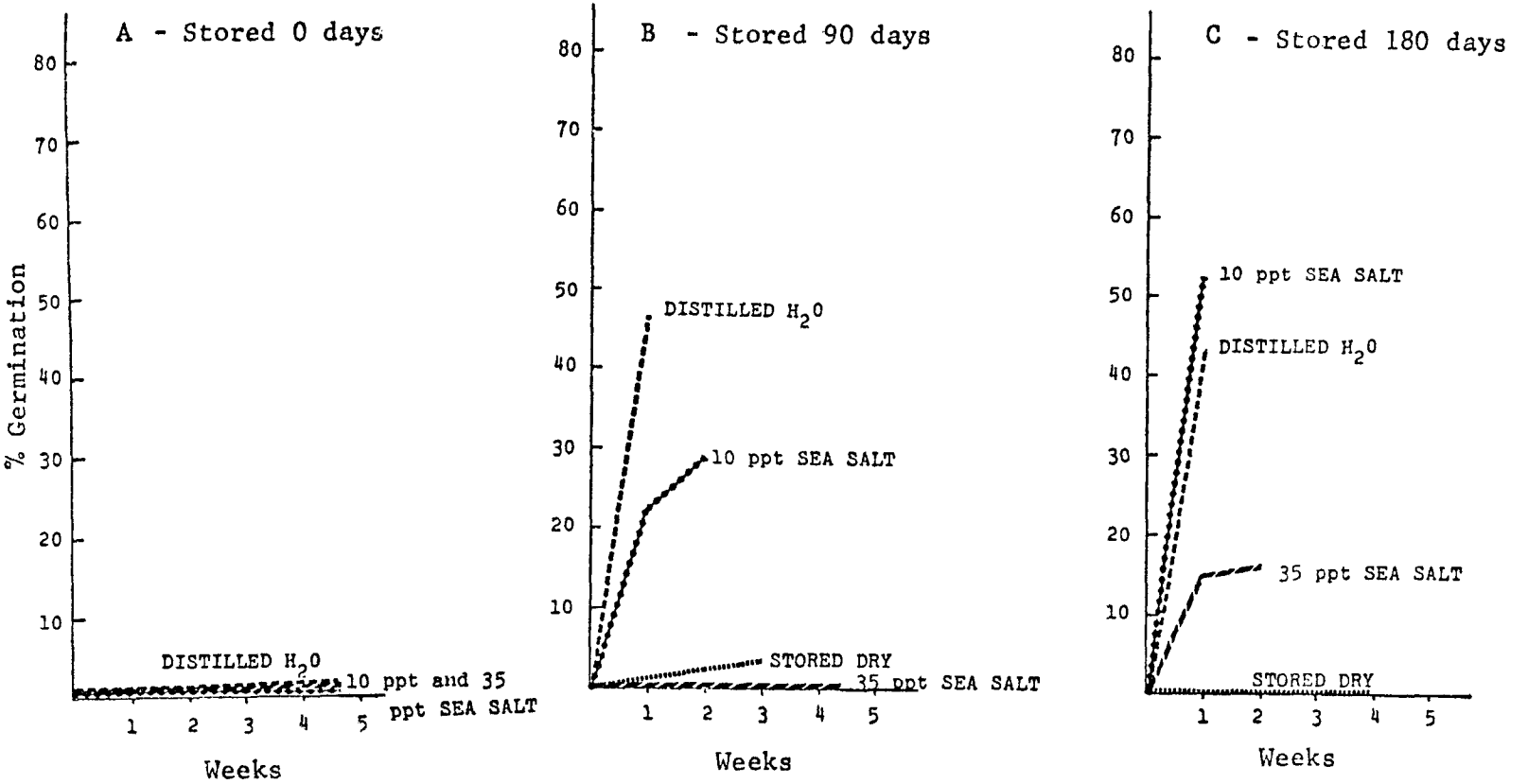

Figure 11. Germination of Iva frutescens at 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

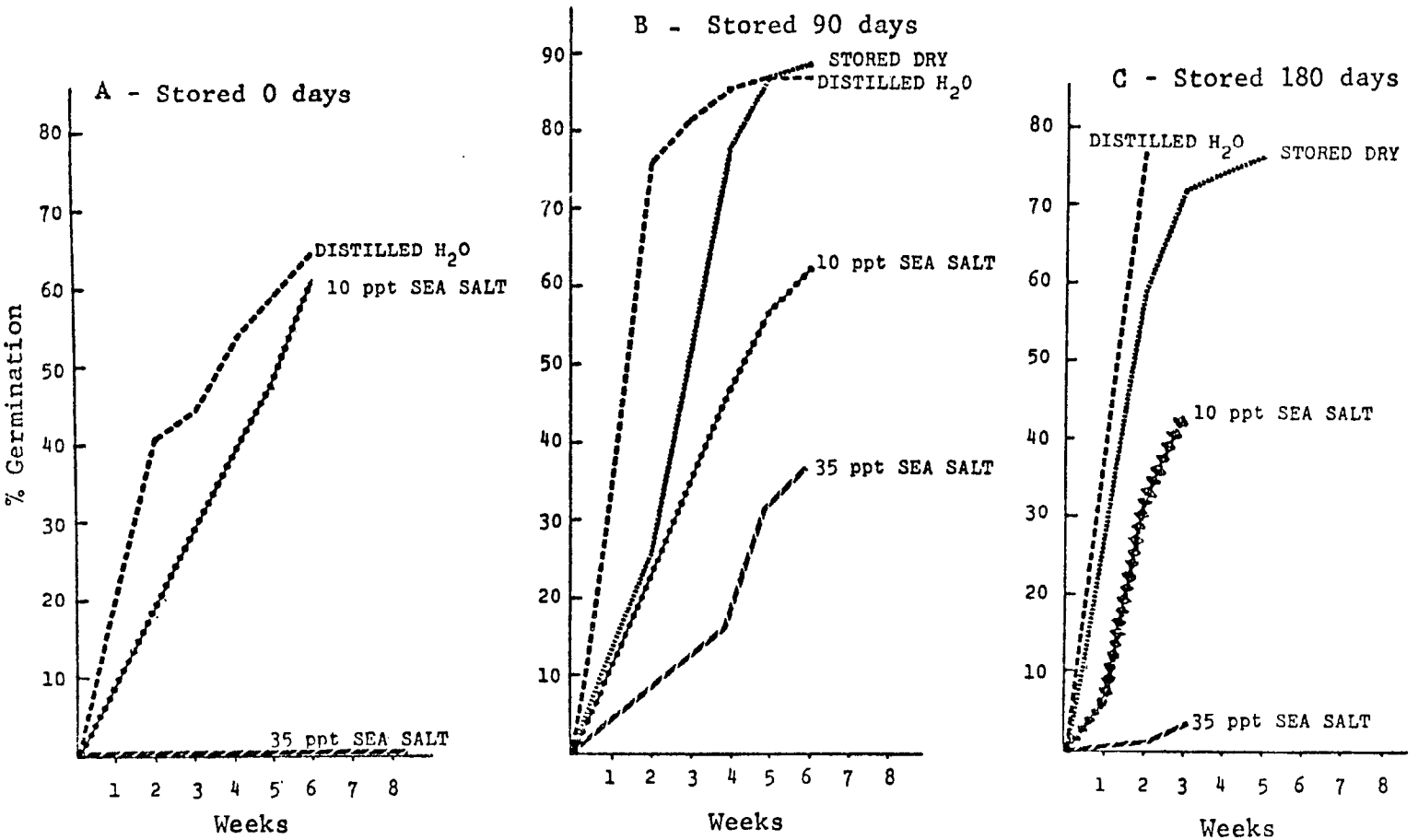

Figure 12. Germination of Juncus effusus at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

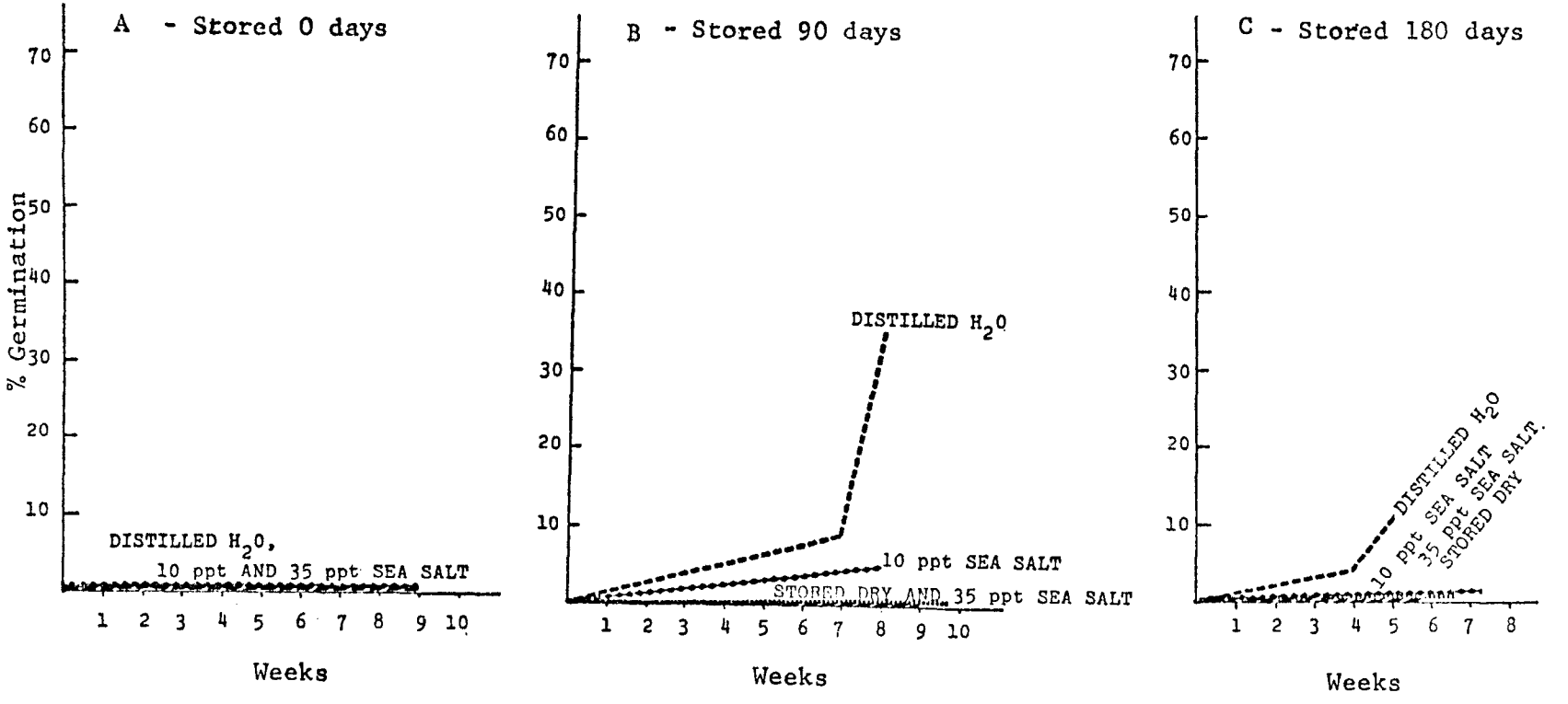

Figure 13. Germination of Juncus effusus at 5-10°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

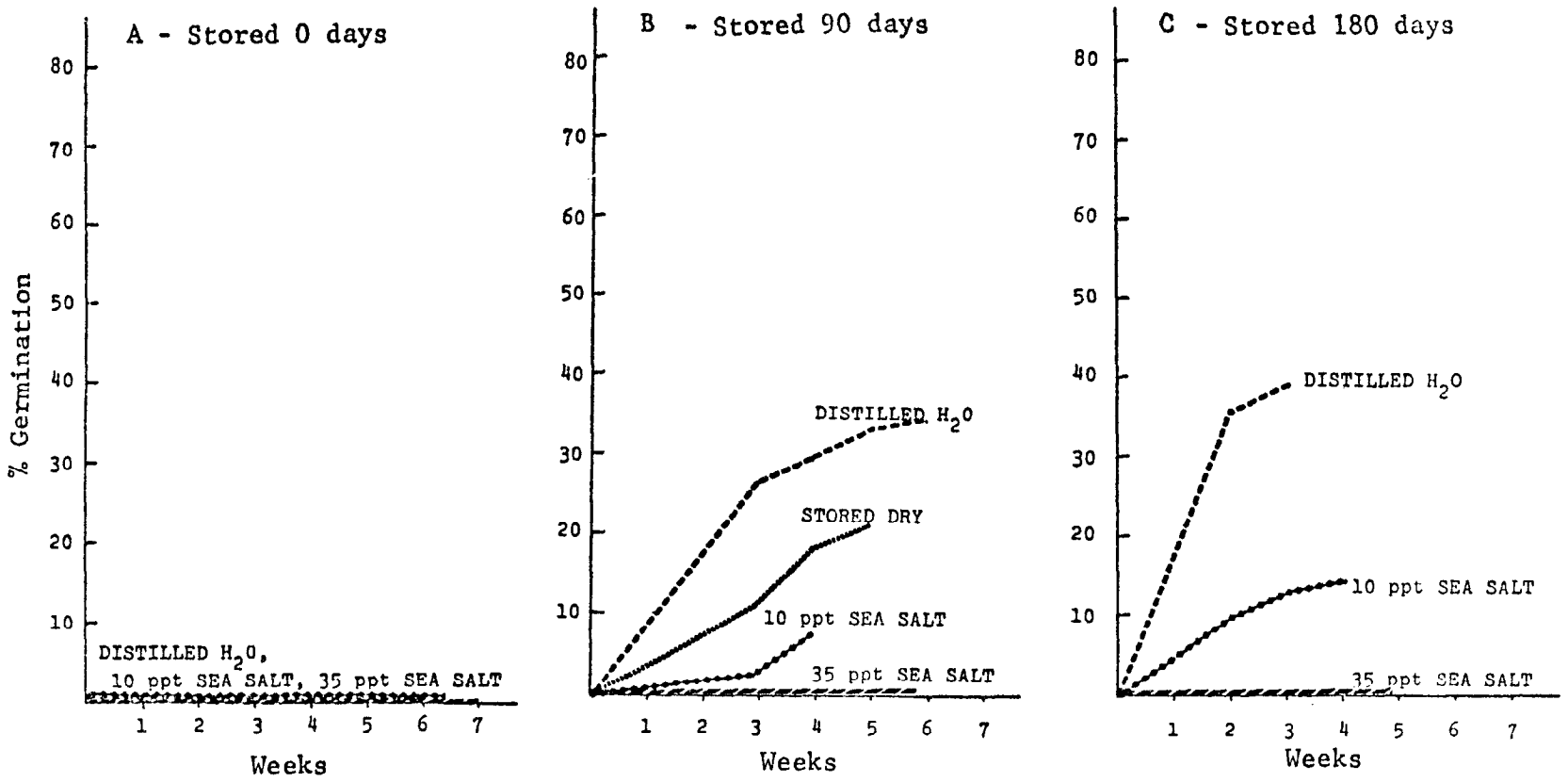

Figure 14. Germination of Sagittaria latifolia at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

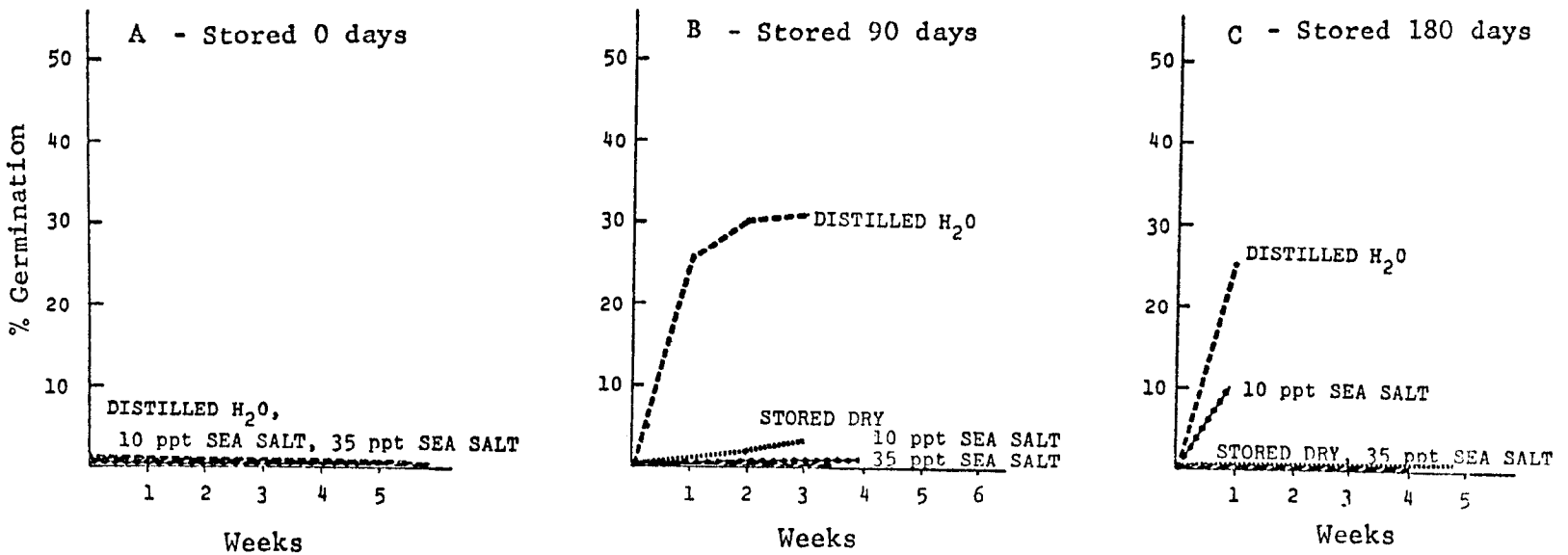

Figure 15. Germination of Sagittaria latifolia at 30°C following 0, 90 and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

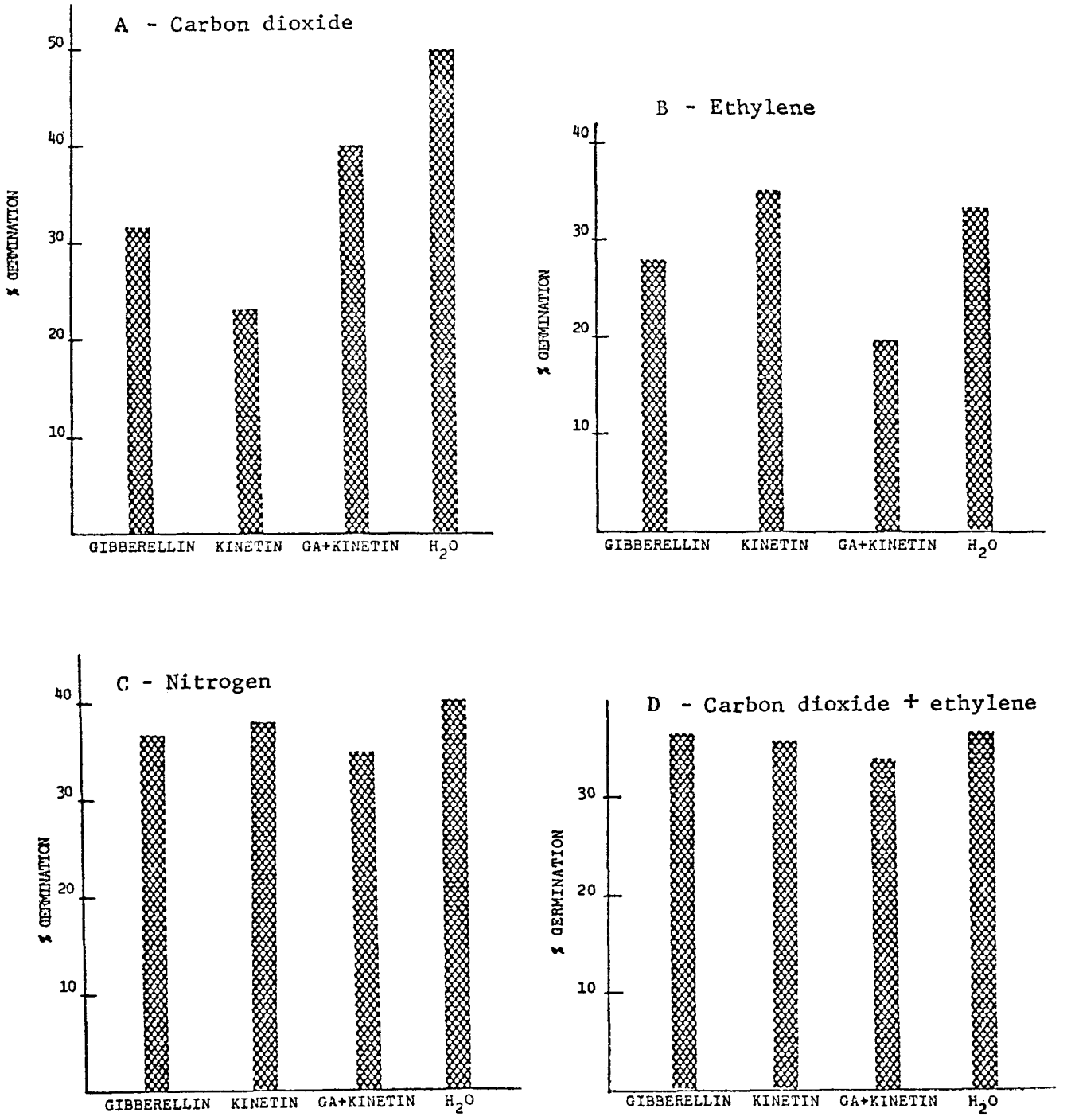

Figure 16. Interaction of gases with gibberellin and kinetin on germination of Sagittaria latifolia

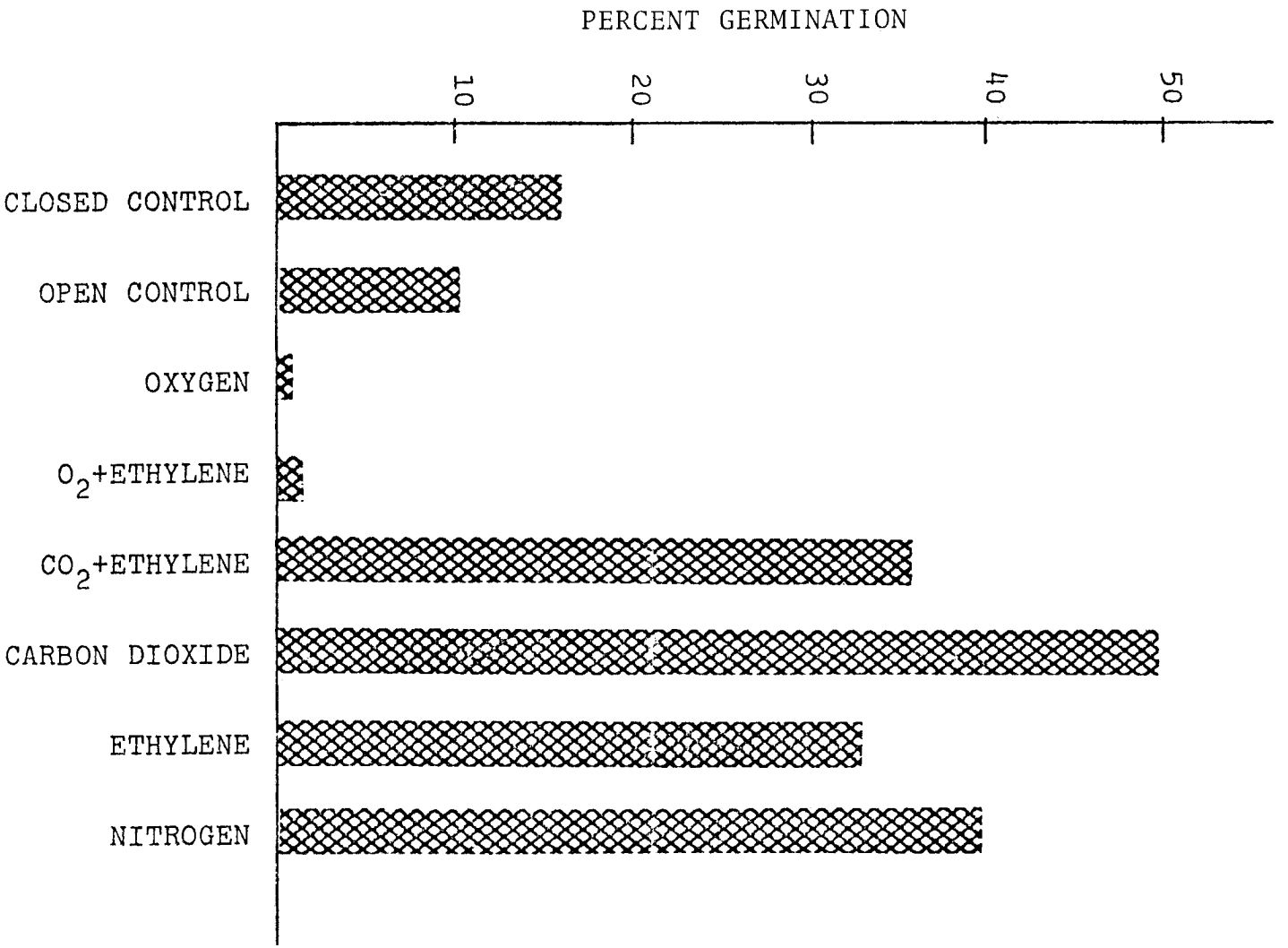

Figure 17. Effects of oxygen, carbon dioxide, nitrogen, and ethylene on germination of Sagittaria latifolia

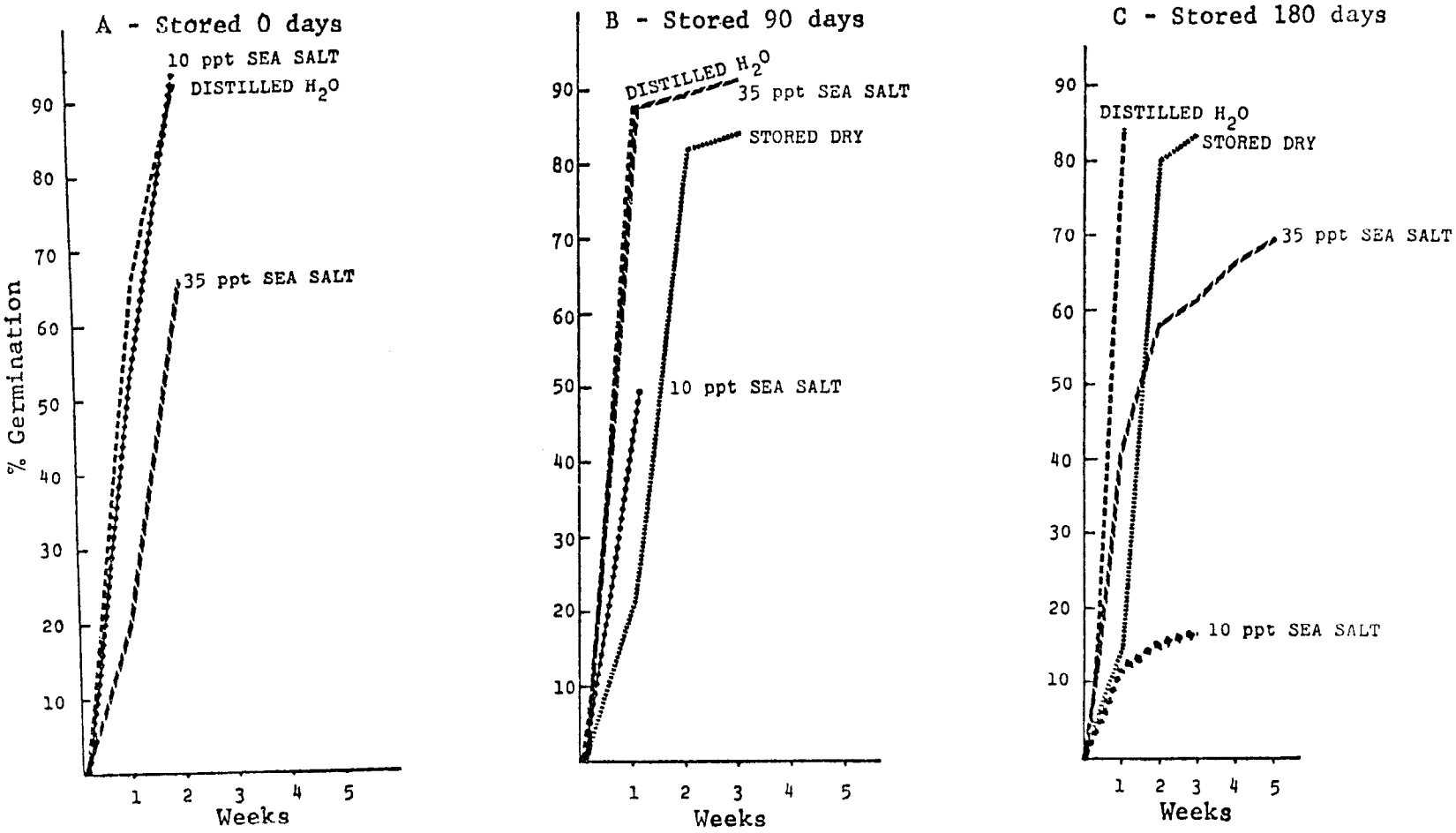

Figure 18. Germination of Salicornia pacifica at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

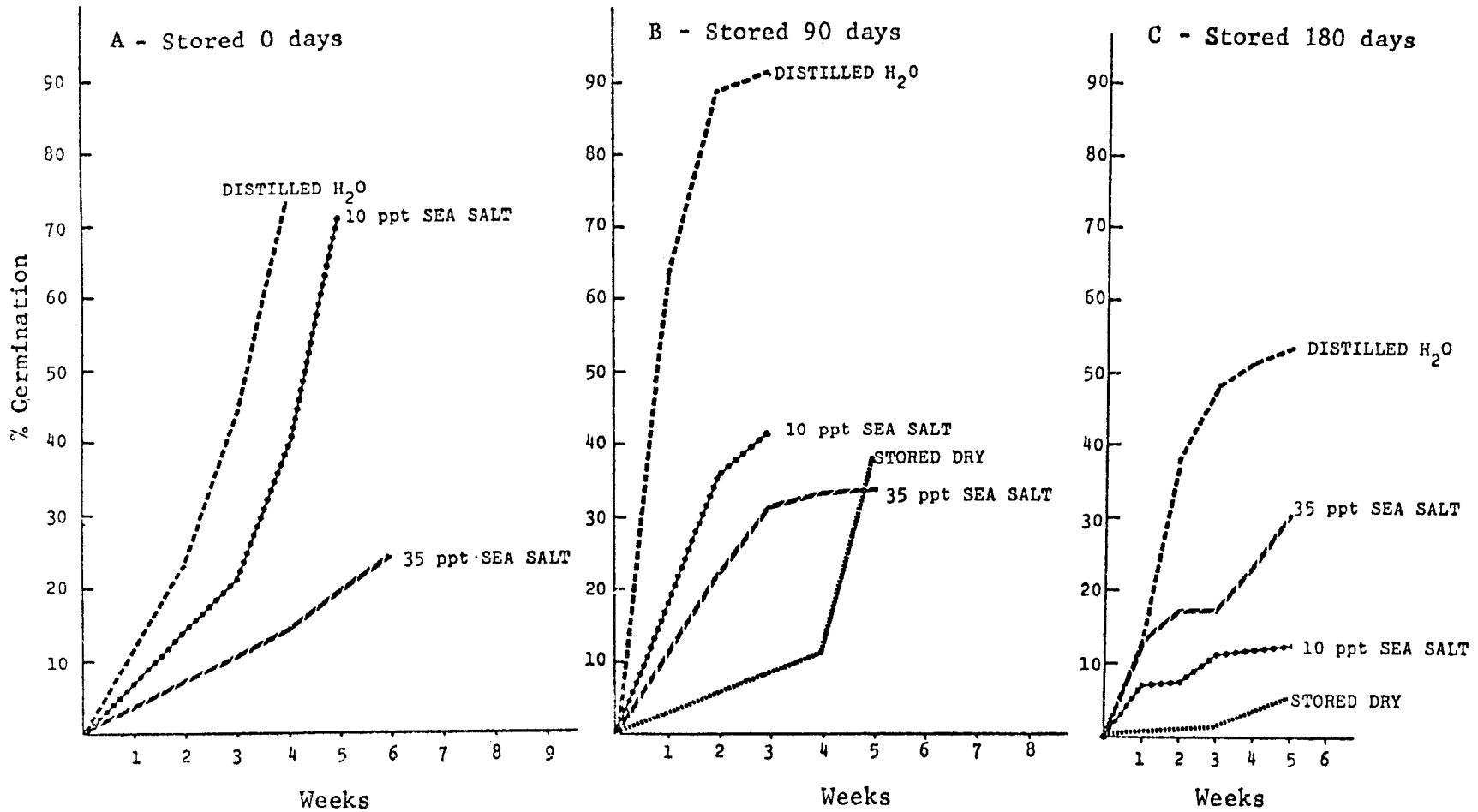

Figure 19. Germination of Salicornia pacifica at 5-10°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

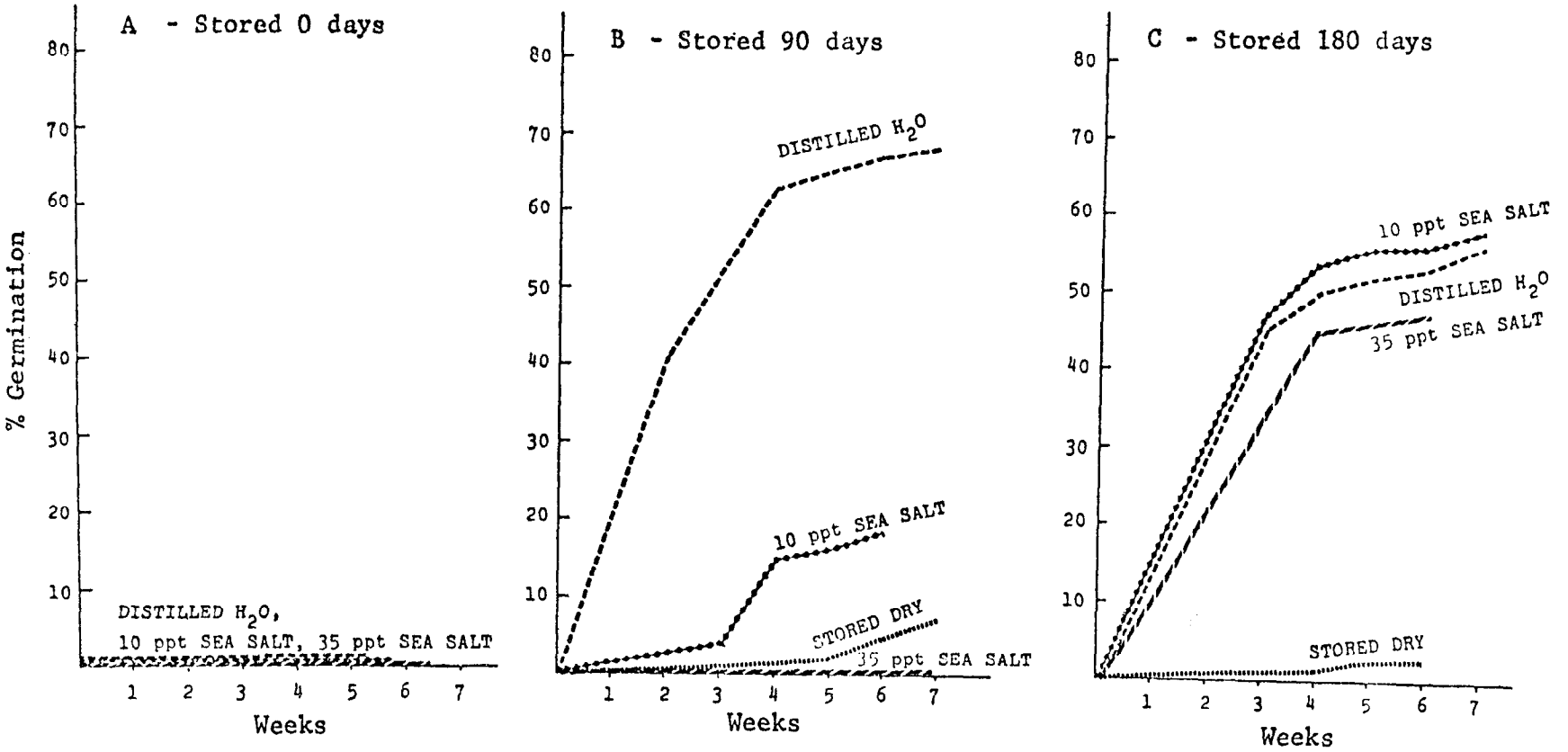

Figure 20. Germination of Scirpus validus at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

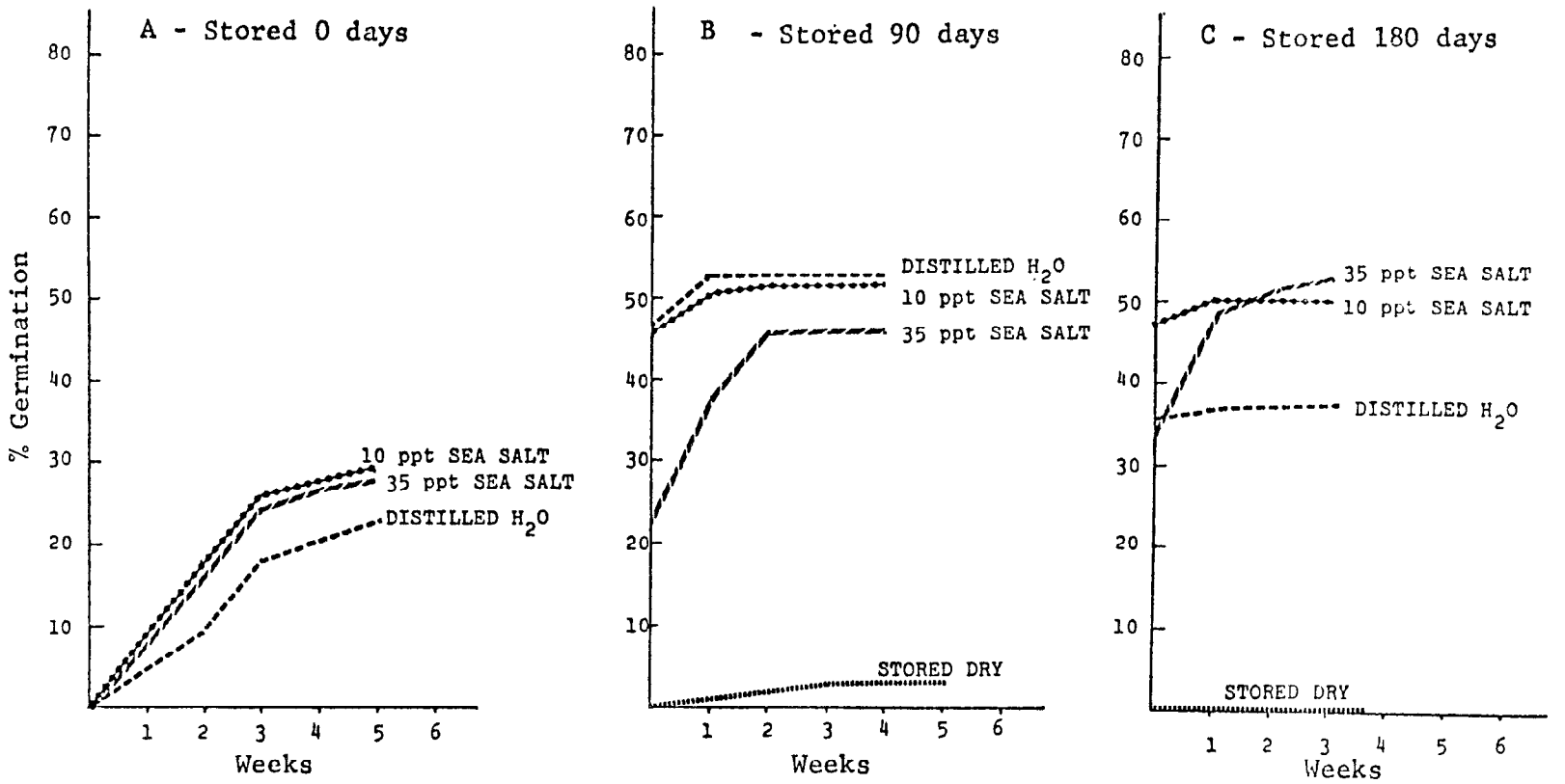

Figure 21. Germination of Spartina alterniflora at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

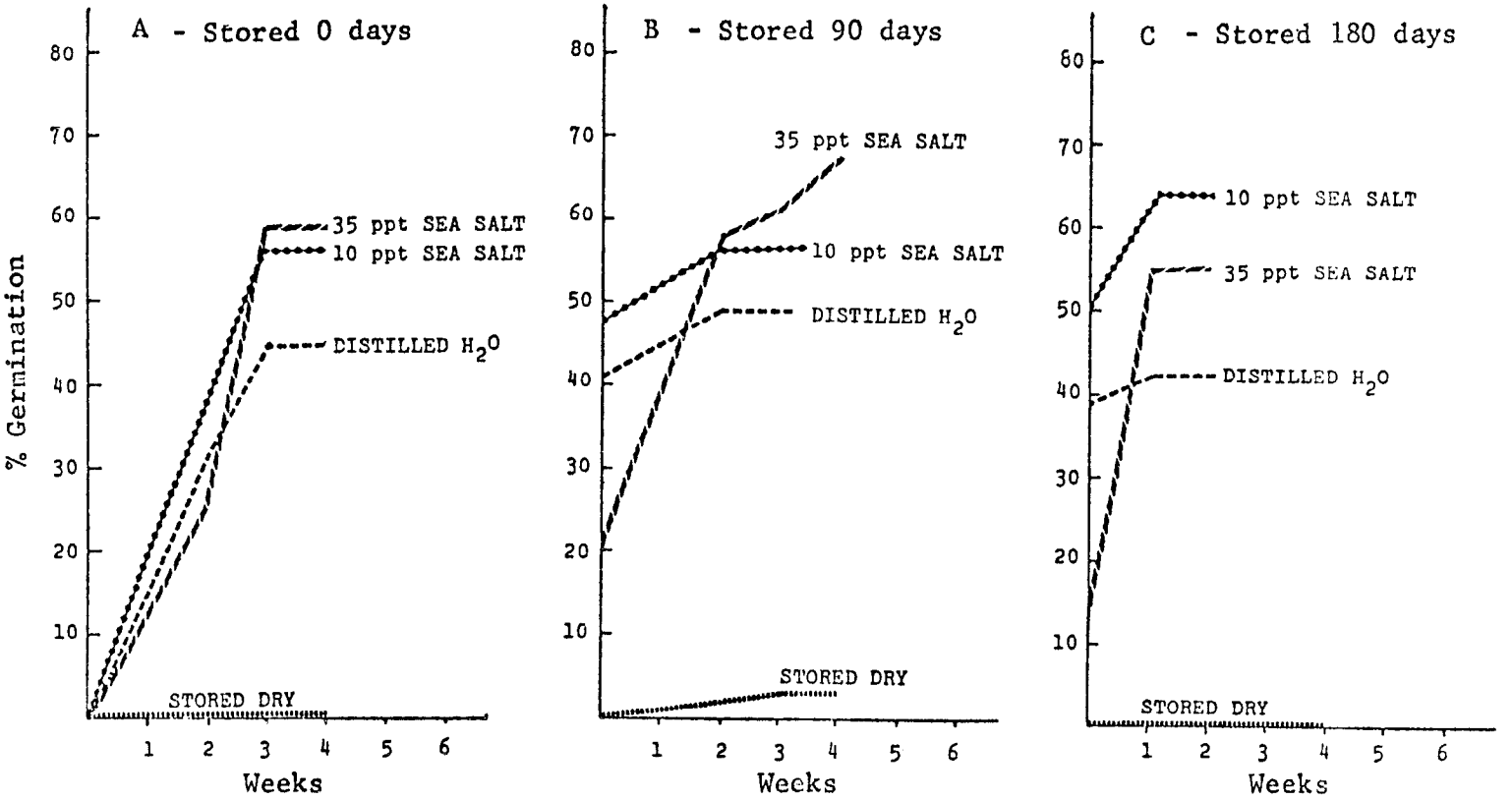

Figure 22. Germination of Spartina alterniflora at 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

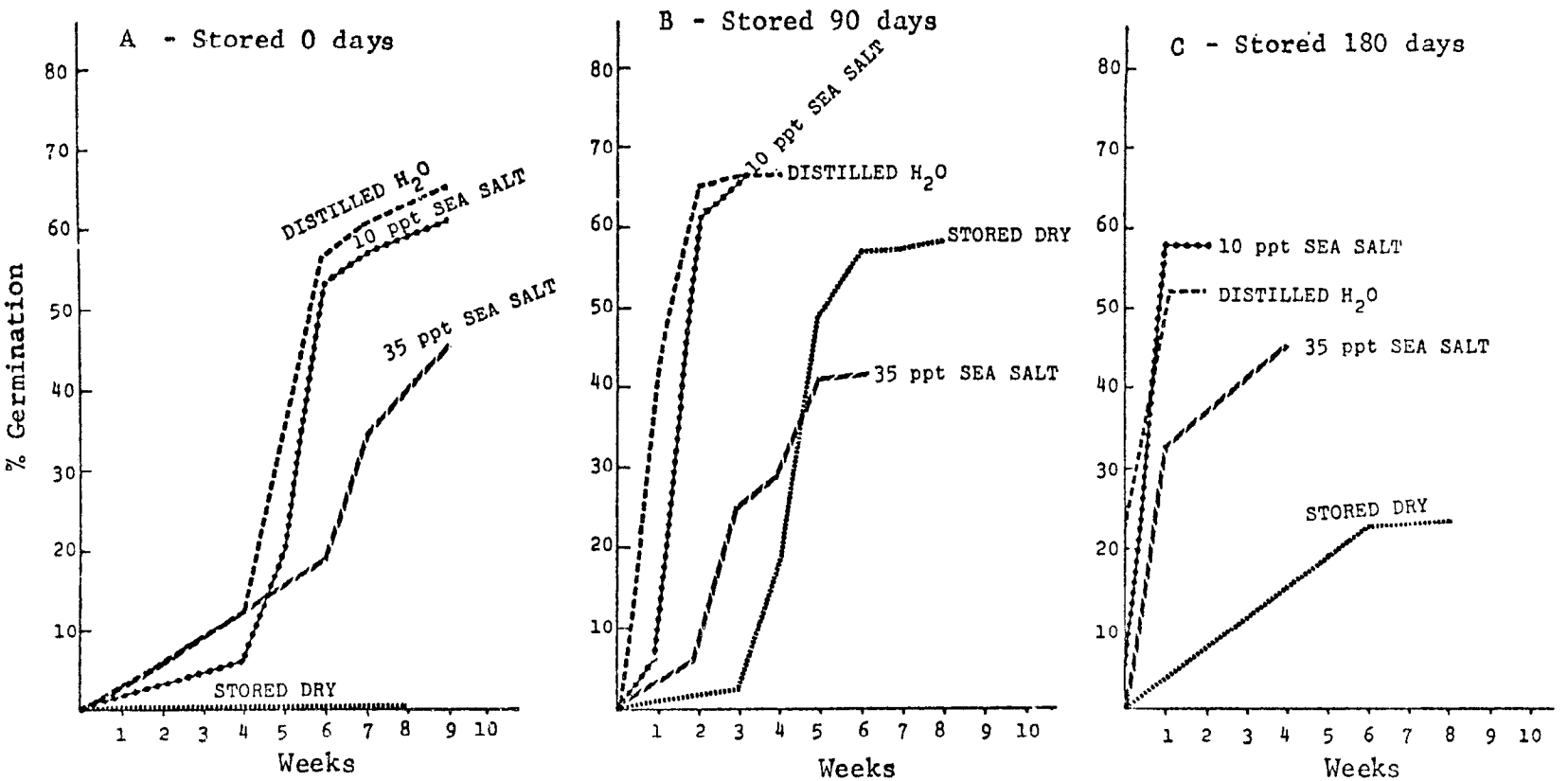

Figure 23. Germination of Spartina cynosuroides at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

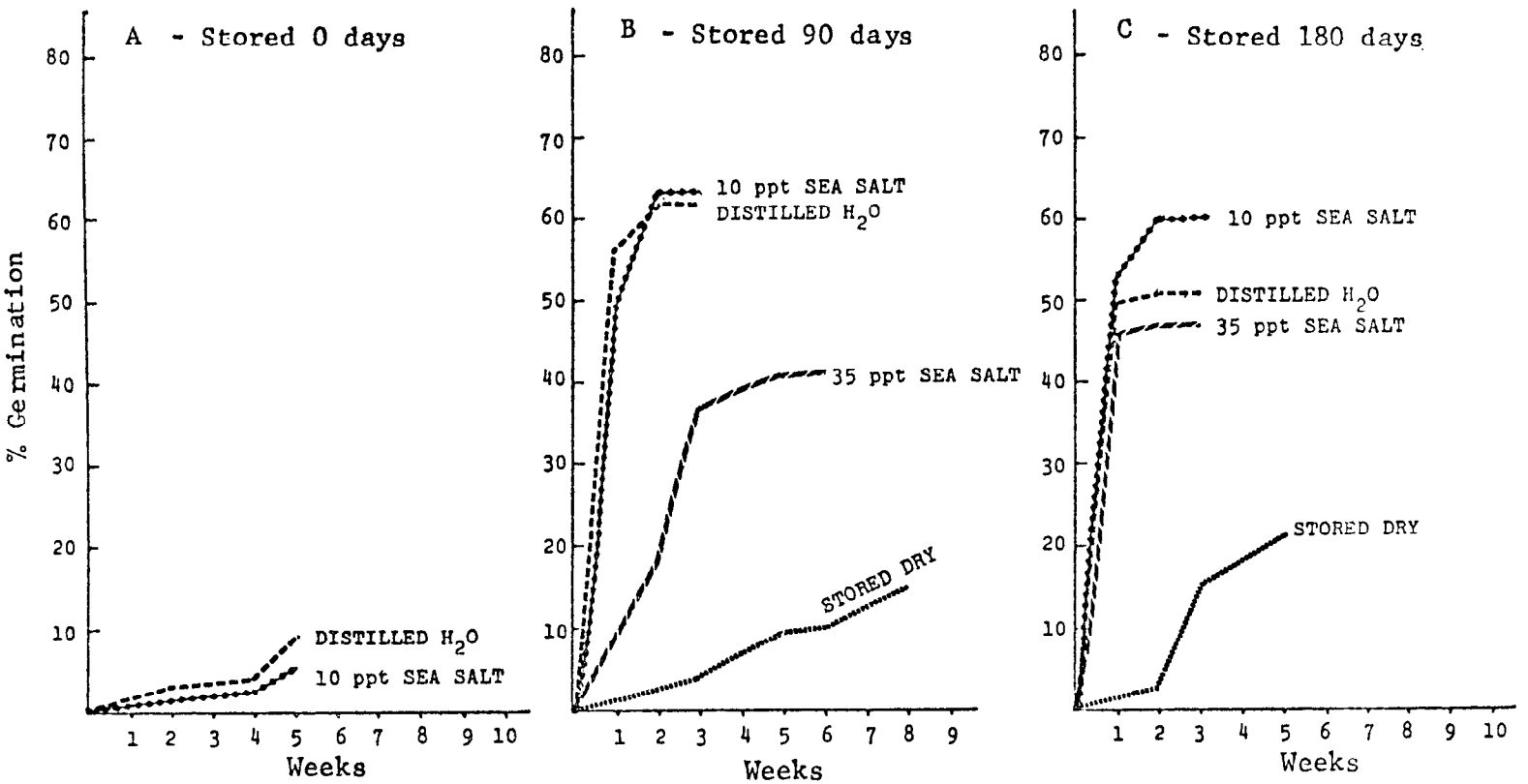

Figure 24. Germination of Spartina cynosuroides at 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

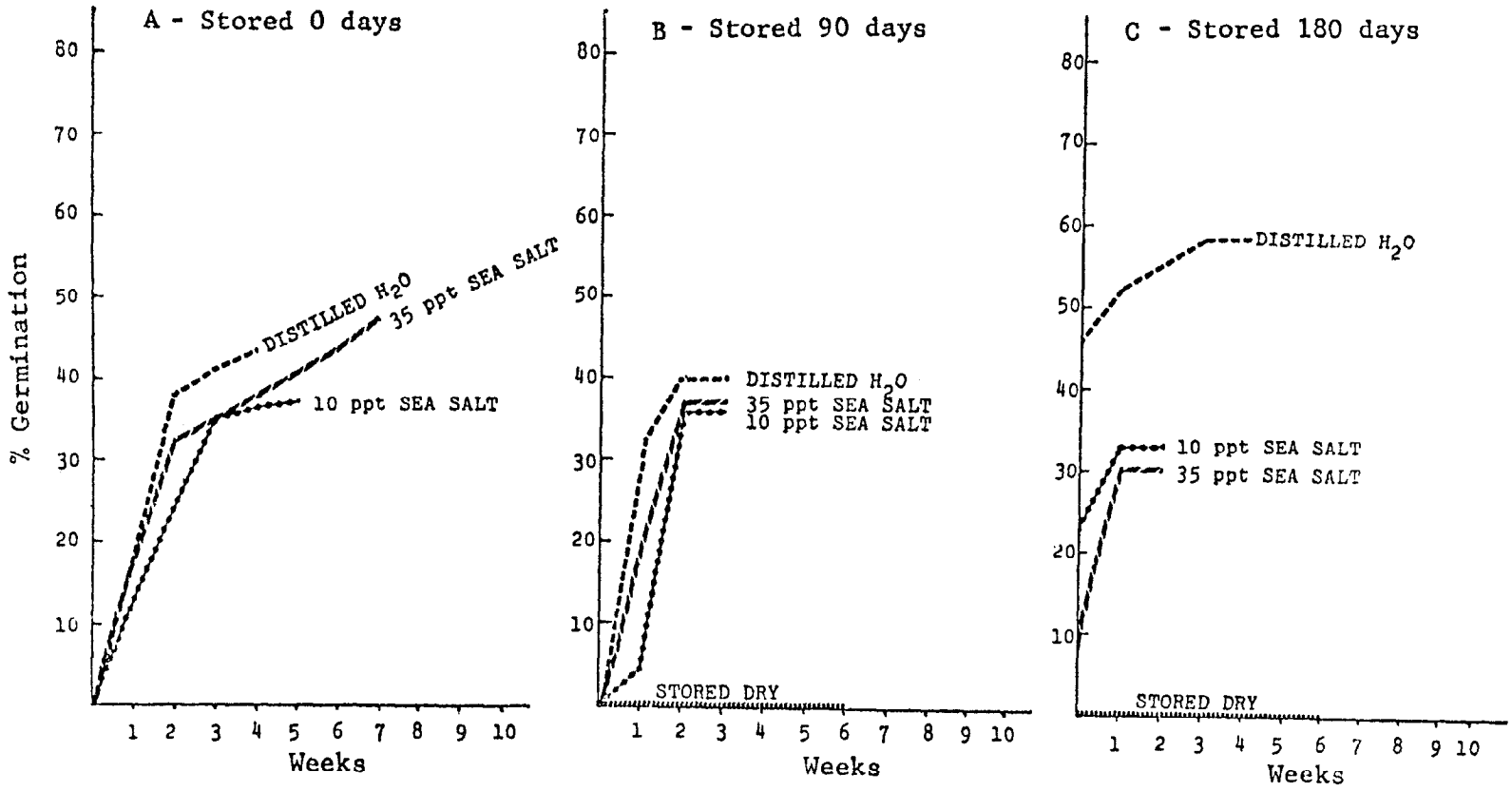

Figure 25. Germination of Spartina foliosa at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

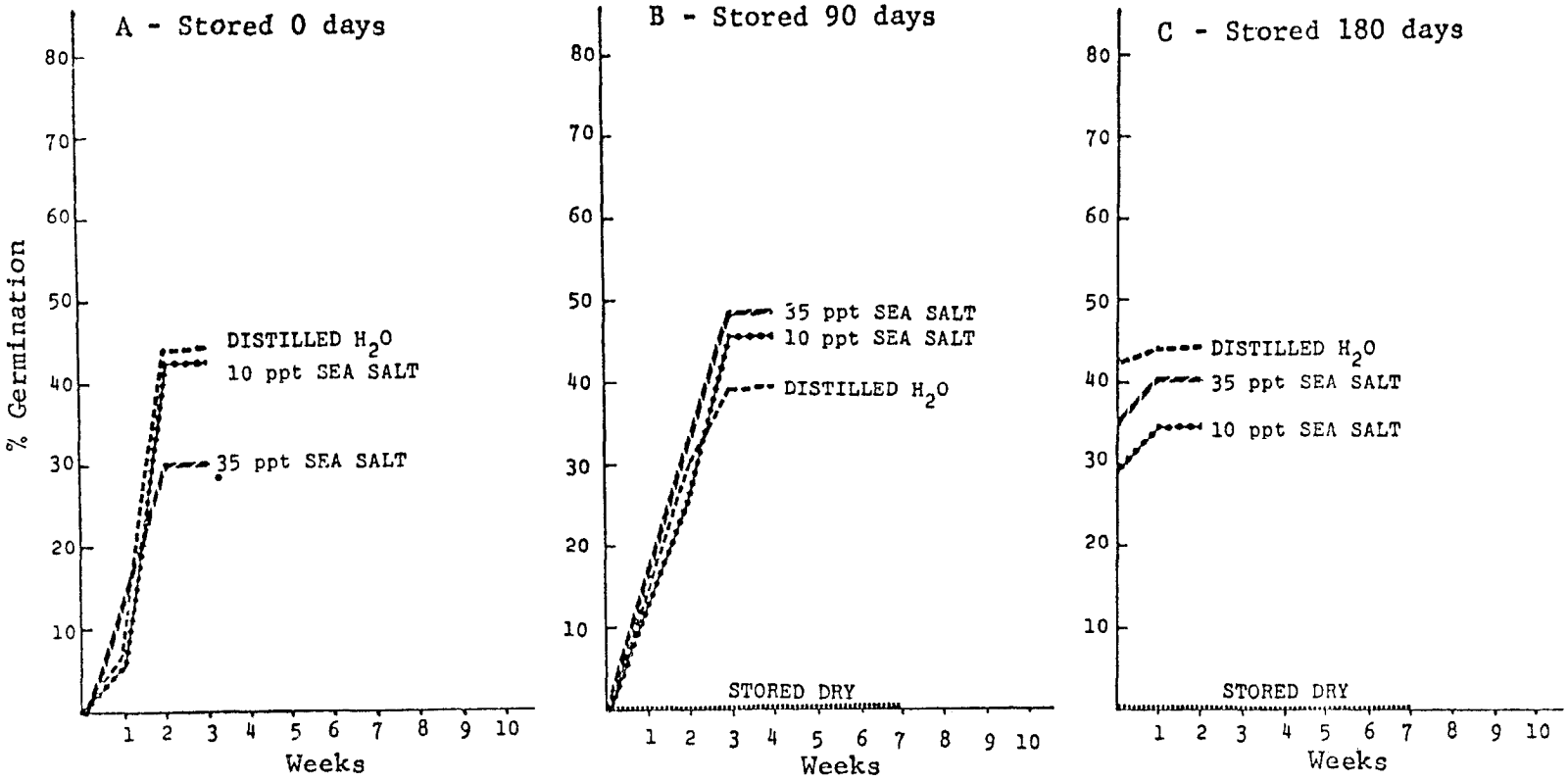

Figure 26. Germination of Spartina foliosa at 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

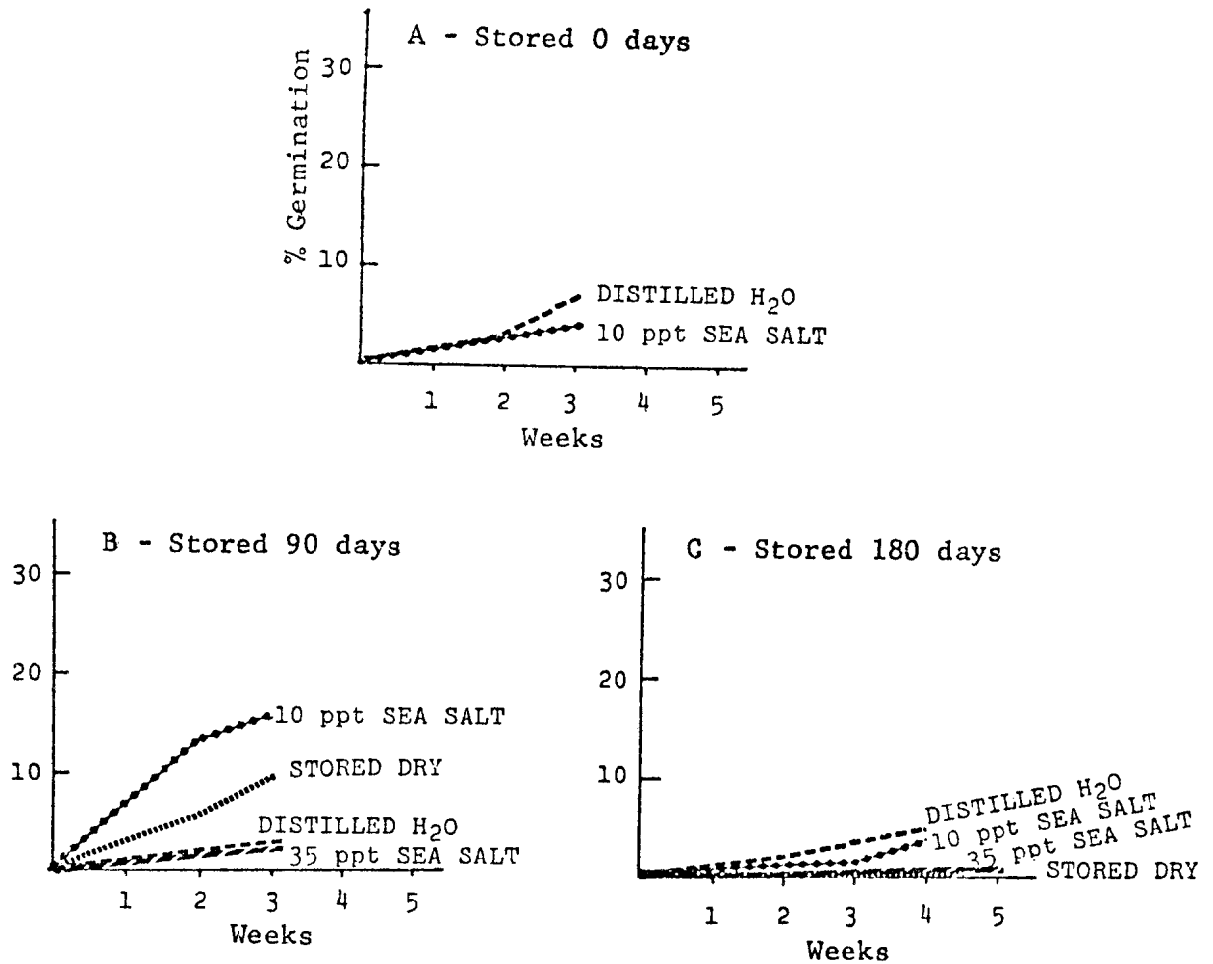

Figure 27. Germination of Spartina patens at 10-25°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

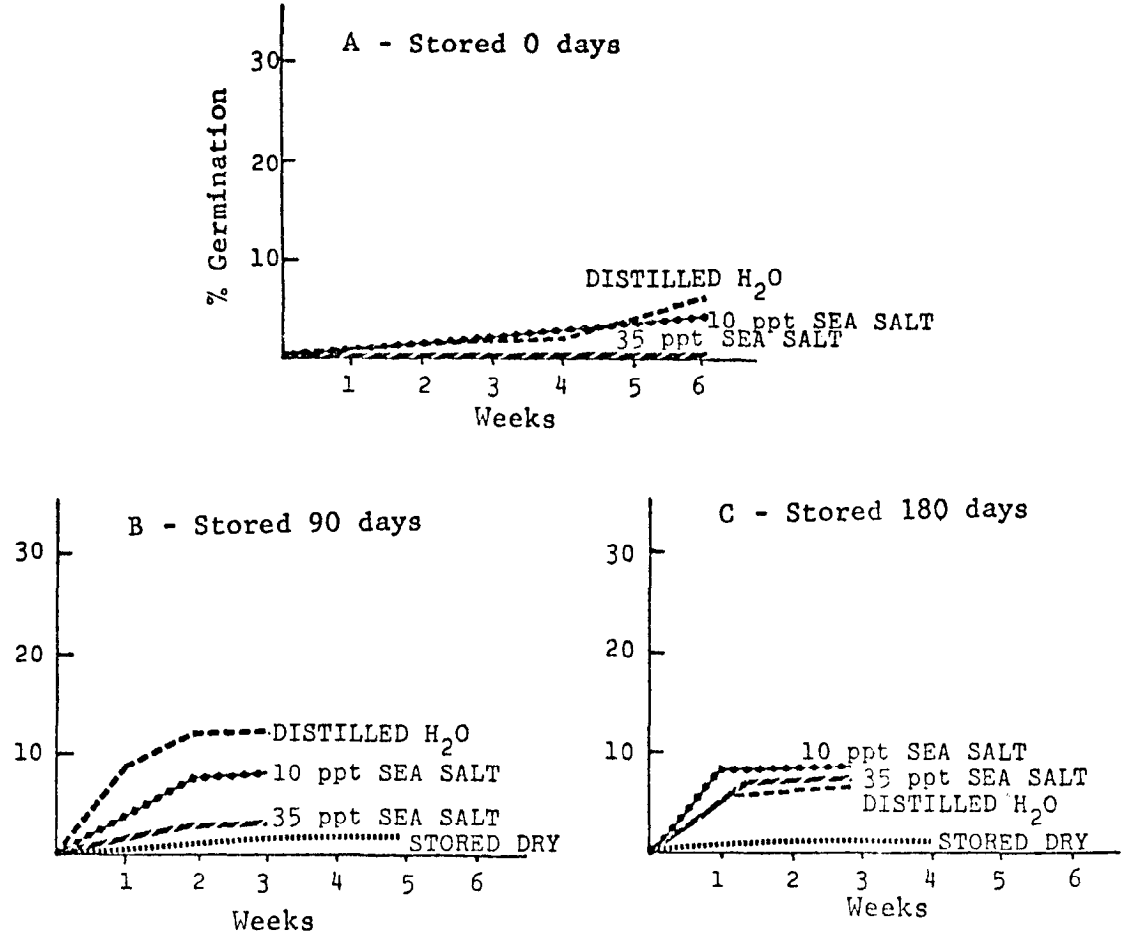

Figure 28. Germination of Spartina patens at 20-35°C following 0, 90, and 180 days stored dry, in distilled water, in 10 ppt salt solution, and in 35 ppt salt solution

APPENDIX A': SCIENTIFIC NAMES AND ASSOCIATED COMMON NAMES USED IN THE TEXT

Appendix A' is a list of common and scientific names used in the text of this report. Common names are listed alphabetically for ease in locating associated scientific names. Several references were needed to develop the species list and those references are listed below:

Correll, Donovan Stewart and Marshall Conring Johnston. 1970. Manual of the Vascular Plants of Texas. George Banta Co., Inc., Menasha, Wisconsin. 1881 pp.

Gleason, Henry A. and Arthur Cronquist. 1965. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. D. Van Nostrand Co., Inc., Princeton, New Jersey. 810 pp.

Hitchcock, C. Leo and Arthur Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press. Seattle. 730 pp.

Munz, Phillip. 1970. A California Flora. Research Journal 31. Agric. Expt. Sta., University of Wyoming, Laramie.

Radford, Albert E., Harry E. Ahles, and C. Ritchie Bell. 1968. Manual of the Vascular Flora of the Carolinas. The University of North Carolina Press. Chapel Hill. 1183 pp.

Common Name	Scientific Name
Apple	*Malus* sp.
Barley	*Hordeum* sp.
Beach grass	*Ammophila breviligulata*
Beach panic	*Panicum amarulum*
Big cordgrass	*Spartina cynosuroides*
Broadleaf arrowhead	*Sagittaria latifolia*
Cocklebur	*Xanthium* sp.
European glasswort	*Salicornia europaea*
Fenugreek	*Trigonella foenum-graecum*
Lettuce	*Lactuca sativa*
Lyngby's sedge	*Carex lyngbyei*
Marsh elder	*Iva frutescens*
Pacific cordgrass	*Spartina foliosa*
Peanut	*Arachis hypogaea*
Pelecote	*Iva annua*
Pickleweed	*Salicornia virginica*
Saltgrass	*Distichlis spicata*
Saltmeadow cordgrass	*Spartina patens*
Sea oats	*Uniola paniculata*
Sea ox-eye	*Borrichia frutescens*
Slough sedge	*Carex obnupta*
Small cranberry	*Vaccinium oxycoccos*
Smooth cordgrass	*Spartina alterniflora*
Soft rush	*Juncus effussus*
Tufted hairgrass	*Deschampsia caespitosa*
Tule	*Scirpus validus*
Veintiunilla	*Asclepias curassavica*
Witchweed	*Striga lutea*
Woody glasswort	*Salicornia pacifica*

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Maguire, J D
Influence of pregermination conditions on the viability of selected marsh plants / by J. D. Maguire, G. A. Heuterman, Seed Technology Laboratory, Washington, State University, Pullman, Wash. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. ; available from National Technical Information Service, 1978.
103, 3 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-78-51)
Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under Contract No. DACW57-76-C-0195 (DMRP Work Unit No. 4A21)
Literature cited: p. 43-46.

1. Germination. 2. Marsh plants. 3. Seeds. 4. Viability. I. Heuterman, G. A., joint author. II. United States. Army. Corps of Engineers. III. Washington (State). State University, Pullman. Seed Technology Laboratory. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-78-51.
TA7.W34 no.D-78-51